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Scotian Shelf Shrimp 2011-2012

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The Fisheries and Oceans Canada-industry survey stratified mean decreased by 18% for the second year in a row. The biomass estimate fell from 37,510 to 30,510 mt. This is consistent with the prediction of a lag between the complete mortality of the long-lived 2001 year class in 2010 and the recruitment of the next moderately abundant 2007-2008 year classes to the fishery in 2012-2013. Although commercial catch per unit efforts were stable (standardised) or increasing (Gulf) the distribution of catch rates are consistent with a declining resource, where areas of very high catch rates continue to decline while areas of low-moderate catch rates are stable or increasing. Spawning stock biomass also declined by about 22%, although the stock remains above the upper limit reference point (i.e. in the Healthy Zone). Although the total allowable catch was reduced to 4600 mt in 2011, this was relatively less of a reduction than the downturns in the point estimated of total and spawning stock biomass, so point estimates of total and female exploitation increased in 2011. Female exploitation increased to 20.3%, just over the removal reference point for this stock. Indices of production suggest that the population is currently composed of very few recruits from the 2010 year class, which is consistent with high spring sea surface temperatures that year. The abundance of age 2 shrimp also declined, as was expected based on low abundance of age 1 shrimp in the belly-bag in 2010. The abundance of age 4 shrimp increased by 50% in 2011, which is consistent with the increase in age 3 shrimp from length-frequency analysis in 2010 and the recruitment of the more abundant 2007 year class to the population. Size-based indicators (size at sex-transition, average maximum size, female size, count) show that the size of shrimp in the population is decreasing. This is consistent with end of the influence of the late-maturing year classes that followed the 2001 year class, and matured as larger than average females, and their replacement by smaller shrimp that are not delaying maturity, as is characteristic of less abundance year classes. The results of the ecosystem characteristic indicators suggest that conditions are currently not favourable for shrimp. Temperatures are increasing and the abundance of sympatric species is decreasing, while the abundance of predators known to have a negative influence on juvenile recruitments is increasing. The overall “traffic light”, summarising 25 stock health indicators, reverted from green to yellow when the 2010 data were finalised, and further reduced to red for 2011, largely due to negative values of production and ecosystem characteristics and the ongoing downturn of abundance, resulting in exploitation increases. Although the index of stock abundance remains in the Healthy Zone, the removal reference was exceeded, albeit barely, in 2011.

RÉSUMÉ

La moyenne stratifiée du relevé de Pêches et Océans Canada (MPO) et de l'industrie a diminué de 18 % pour la deuxième année consécutive. L'estimation de la biomasse a chuté de 37 510 à 30 510 t. Cette chute correspond à la prévision d'un décalage temporel entre la mortalité complète de la classe d'âge 2001 (dont l'espérance de vie est élevée) en 2010 et le recrutement à la pêche en 2012-2013 des prochaines classes d'âges modérément abondantes de 2007-2008. Malgré la stabilité des captures par unité d'effort (CPUE) de la pêche commerciale (normalisées) ou malgré leur augmentation (Golfe), la répartition des taux de captures s'aligne sur des ressources décroissantes, où les zones dans lesquelles les taux de captures sont très élevés continuent de diminuer tandis que les zones où les taux de captures sont faibles à modérés sont sables ou croissants. La biomasse du stock reproducteur a aussi diminué d'environ 22 %, mais le stock reste supérieur au point de référence de la limite supérieure (c.-à-d. dans la zone saine). Le total autorisé des captures a été réduit à 4 600 t en 2011; cependant, comme il s'agit d'une diminution relativement moins importante que dans les estimations ponctuelles de la biomasse totale et de la biomasse du stock reproducteur, les estimations ponctuelles du taux d'exploitation total et du taux d'exploitation des femelles ont augmenté en 2011. Le taux d'exploitation des femelles a augmenté; il est passé à 20,3 %, tout juste au-delà du point d'exploitation de référence pour ce stock. Les indices de production laissent supposer que la population est actuellement composée de très peu de recrues de la classe d'âge 2010 en raison des fortes températures de la surface de l'eau au printemps cette année. L'abondance des crevettes d'âge 2 a aussi diminué, comme il avait été prévu étant donné la faible abondance des crevettes d'âge 1 dans le sac ventral en 2010. L'abondance des crevettes d'âge 4 a augmenté de 50 % en 2011, ce qui correspond à l'augmentation dans l'abondance des crevettes d'âge 3 dans l'analyse sur la fréquence de longueur en 2010 et au recrutement de la classe d'âge abondante de 2007 à la population. Les indicateurs fondés sur la taille (taille lors du changement de sexe, taille moyenne maximale, taille des femelles, nombre de crevettes) indiquent que la taille de la crevette dans la population diminue. Cela coïncide avec la fin de l'influence exercée par les classes d'âge à maturité tardive qui ont suivi la classe d'âge 2001 et dont la taille au moment d'atteindre la maturité sexuelle en tant que femelle était supérieure à la moyenne; par ailleurs, le remplacement par des crevettes plus petites ne retarde pas l'atteinte de la maturité, une caractéristique des classes d'âge moins abondantes. Les résultats des indicateurs des caractéristiques écosystémiques laissent supposer que les conditions actuelles ne sont pas favorables pour la crevette. Les températures augmentent et l'abondance des espèces sympatriques diminue, tandis que l'abondance des prédateurs ayant une influence négative sur le recrutement des juvéniles augmente. Les « feux de circulation » globaux, qui reprennent 25 indicateurs de l'état du stock, sont passés de vert à jaune lorsque les données de 2010 ont été finalisées, puis à rouge en 2011; cette chute est due en grande partie aux valeurs négatives des caractéristiques de la production et de l'écosystème, ainsi qu'à la diminution continue de l'abondance provoquée par des augmentations dans l'exploitation. Bien que l'indice de l'abondance du stock se maintienne dans la zone saine, le point de référence de prélèvement a été dépassé, de très peu, en 2011.

INTRODUCTION

The biology of northern shrimp, *Pandalus borealis*, is reviewed in Shumway et al. (1985) for various stocks world-wide, and by Koeller (1996a, 2000, 2006) and Koeller et al. (2000a, 2003a) for the eastern Scotian Shelf stock. The rationale for the assessment and management approach used is described in Koeller et al. (2000b). The history of the eastern Scotian Shelf shrimp fishery and recent stock assessments are given in Koeller (1996b) and Koeller et al. (1996, 1997, 1998, 1999, 2001, 2002, 2003b, 2004, 2005, 2006a, 2006b, 2008, 2009a, 2011) and Hardie et al. (2011). Although there has been some shrimp fishing on the Scotian Shelf since the 1960s, the Nova Scotia fishery began to expand toward its full potential only when groundfish bycatch restrictions were overcome with the introduction of the Nordmøre grate in 1991. The total allowable catch (TAC) was first reached in 1994, when individual Shrimp Fishing Area (SFAs) quotas were removed. With biomass at historical highs and continued good recruitment, the TAC was raised from 3100 mt to 3600 mt for 1997 and to 3800 mt for 1998. Despite evidence of reduced recruitment to the population, and because of continued high spawning stock biomasses (SSBs) and large year classes (1993-1995) recruiting to the fishery, the TAC was increased to 5000 mt for 1999 and to 5500 mt for 2000. With the strong year classes completing their life cycle; recruitment only average; a decreasing trend in the survey biomass; increasing exploitation rates; changes in the distribution of the resource; and increasing harvest levels during the ovigerous period, the TAC was reduced to 5000 mt for 2001 and to 3000 mt for 2002 and 2003. In 2003, the survey index increased for the first time following three successive declines and the TAC was raised to 3500 mt for 2004. Signs of improved recruitment in the form of a very strong 2001 year class suggested that the stock would continue to increase. The 2004 survey biomass was the highest on record and the TAC was raised to 5000 mt for the 2005 fishery. Despite a declining trend since 2004, biomass has remained relatively high, especially in SFA 14. Consequently, TACs were kept at 5000 mt for the 2006-2008 fisheries. With the 2001 year class at or past normal life expectancy, below average recruitment following, and a large biomass decrease in SFA 14, biomass was predicted to continue decreasing. Consequently the TAC for 2009 was decreased to 3500 to prevent an increase in the exploitation rate. A problem with the angle of attack of the Nordmøre grate in the survey trawl was discovered and rectified for the 2009 survey. The survey abundance index increased nearly 50% to the second highest value on record in 2009. The degree to which this increase, and the underestimation of the population in preceding years, can be attributed to the degeneration and refurbishment of the survey trawl is discussed in Koeller et al. (2011). In general, the increase in the survey index in 2009 can be attributed to both the increased catchability with the refurbished trawl and increased biomass, the latter due, in part, to the unexpected continued contribution of the 2001 year class beyond its expected lifespan. As a result, the TAC for 2010 was set at 5000 mt. The trawl was carefully inspected prior to the 2010 survey. A new trawl was used in 2011, which was built to the specifications of the previous trawls, and once again carefully inspected before and during the 2011 survey.

Since 1999, many shrimp stock assessments have included a “Traffic Light” analysis (Koeller et al. 2000b, Mohn et al. 2001, Halliday et al. 2001). The organisation of this report is based on this multiple indicator diagnostic approach, with the “Methods” and “Results and Discussion” sections for individual indicators grouped under headings representing "characteristics," in the order they are presented in the summary. The sections on each indicator in “Methods” provide the methods used to calculate the indicators, and describe their relevance to the characteristic they represent. In “Results and Discussion,” the indicators always represent summary data for the entire area, i.e. all SFAs combined, according to the current practice of managing the fishery as one stock. The indicator series used in the analysis is given as an uncaptioned figure directly after the indicator heading. In addition to the indicator time series themselves, their sections in “Results and Discussion” include data which support trends seen in the summarised data.

These data are given as numbered and captioned figures and tables at the end of the document. For example, individual SFA data often replicate the indicator trends and thus substantiate them. Supporting data may be quite independent from the data used to derive the main indicator. For example: catch rates in the shrimp trap fishery supported the apparent increasing shrimp aggregation shown by the survey and catch per unit effort (CPUE) data; anecdotal reports of large numbers of age 1 shrimp found on Cape Breton beaches in 2002 supported survey data indicating a strong 2001 year class, etc. This additional information may be used in the interpretation associated with any change that is given in the "Results and Discussion," but it is not used in the summary traffic light "scores." In any case, it should be noted that such scoring is not intended to be translated directly into management action, for example, in the form of rules linked to summary scores. The "Traffic Light" is currently seen simply as a tool for displaying, summarising, and synthesising a large number of relevant yet disparate data sources into a consensus opinion on the health of the stock. A precautionary approach using reference points and control rules within the framework of the Traffic Light analysis was first reviewed during the Fisheries and Oceans Canada (DFO) Maritimes 2009 Regional Advisory Process meeting. That approach has since been modified and included in the new Integrated Fisheries Management Plan in 2011. In general, the precautionary application of reference points for eastern Scotian Shelf shrimp includes:

1. **Lower Limit Reference Point (LRP)**: 30% of the average SSB (5459 mt) maintained during the modern fishery (2000-2010[1]). The LRP is approximately equal to the average SSB during the low-productivity (pre-1990) period for this stock, characterised by low shrimp abundance, high groundfish abundance and relatively warm temperatures. The Scotian Shelf shrimp population previously increased from low level during the transition from low- to high-productivity, so the working assumption is that shrimp could once again recover from this level given appropriate environmental conditions and fishing pressure (i.e. $B_{recover}$ proxy). Secondly, given the important role of shrimp in the Scotian Shelf ecosystem, particularly as prey for groundfish, this LRP is set to avoid a decrease in shrimp abundance below the level at which it was previously able to fulfill its ecosystem roles under a situation of high groundfish abundance (i.e. to avoid a scenario in which low shrimp abundance could act as a limiting factor in groundfish non-recovery).
2. **Upper Limit Reference Point (URP)**: 80% of the average SSB (14558 mt) maintained during the modern fishery (2000-2010[1]). The URP has been selected at the default value (80%) and to maintain a sufficient gap between the LRP and URP to account for uncertainty in the stock and removal reference values, and to provide sufficient time for biological changes in the population to be expressed, detected and acted upon.
3. **Removal Reference Point**: The removal reference for Scotian Shelf shrimp is 20% female exploitation (actual female catch/SSB) when above the URP. This exploitation rate has rarely been exceeded during the modern fishery (2000-present), a period during which high CPUE and SSB have been maintained. Additionally, given that shrimp survive for approximately three to four years after their recruitment to the fishery, it can be approximated that on the order of 25-33% of the fishable biomass would be subject to natural mortality in any given year. As a result, the removal reference of 20% for shrimp is on the conservative side of this simplistic estimation of natural mortality (25-33%). Although exploitation scenarios in which fishing mortality equals natural mortality may

[1] The reference points are set based on data from 2000-2010 to avoid a scenario whereby reference points based on a moving average would become *less* conservative during a period of a biomass downturn. This action does not negate the need to be vigilant for signs of a shift away from the current high productivity regime towards a lower productivity regime in which these reference points may no longer be suitable.

result in optimal yield (e.g. Gulland 1971), more recent work has suggested that this is an overly risky exploitation strategy. As a result, the maximum removal reference of 20% for shrimp is on the conservative side of the simplistic approximate range of natural mortality (25-33%).

At SSB levels below the LRP the fishery is closed. A suite of approximately 20 secondary indicators of shrimp abundance and production, fishing effects and environmental conditions provide a scientific interpretation of holistic data to inform the way in which science advises responding to the stock status and removal relative to reference points.

The shrimp fishing areas on the Scotian Shelf are shown in Figure 2. Table 1 provides basic catch statistics for the fishery since 1980, and Table 2 gives licensing information for the recent period covered under sharing agreements between the Nova Scotia and Gulf fleets. It currently operates under an 'evergreen' Integrated Fisheries Management Plan (Scotian Shelf Shrimp Integrated Fisheries Management Plan, version 1.5.2, November 29, 2011).

The experimental trap fishery was not under quota management from 1995-1998 except for a 500 mt precautionary "cap". As a result, the total catch tended to exceed the TAC due to the trap fishery. When the trap fishery in Chedabucto Bay was made permanent in 1999, a trap quota was set at 10% of the total TAC, e.g. 500 mt of the 5000 mt TAC. The reallocation of any uncaught portion of the trap quota late in the year resulted in some fishers being unable to take advantage of the additional quota. This often contributed to an overall catch lower than the TAC. In an attempt to avoid reallocations, in 2004, only 300 mt were allocated to this fishery, which is closer to its capacity. With an increase in the TAC for 2005, this was increased to 392 mt, but trap fishing effort and catch were very low during 2005-2010 due to poor market conditions. In 2011, a buyer/processor has committed to the shrimp trap association and is marketing the trap shrimp as a high-end product exported to Japan. The trappers are currently getting the best price ever received for these shrimp. The 2011 southern Chedabucto Bay trap fishery began in early September with one vessel fishing approximately 35 traps. By mid November, six vessels had begun actively fishing their full complement of 100 traps each with an average catch per trap haul (CPTH) of approximately 7 lbs. Hail-in estimates during two weeks in November total 22 tonnes of shrimp landed after 7300 trap hauls. There have been considerably higher landings in 2011 (due to new market) than in the past several years. Trap landings for 2011 could be in the range of 85 t, higher than any year since 2004.

METHODS AND MATERIALS

TRAFFIC LIGHT INDICATORS

Default boundaries between traffic lights for individual indicators, i.e. transition from green to yellow and from yellow to red were arbitrarily taken as the 0.66 and 0.33 percentiles, respectively, of the data in the series, unless an increase was considered bad for stock health, in which case these were reversed. Note that for commercial CPUE series, the "polarity" of the default boundary should be considered with other indicators for certain years. For example, increased CPUE series coupled with increased aggregation and decreased survey abundance would be viewed as a negative development. Traffic lights were not changed from the default in this document (Koeller et al. 2002). Data series vary in length from 10-30 years depending on the availability of data for each indicator.

ABUNDANCE

Research Vessel Abundance Index

The 17th DFO-industry trawl survey, incorporating a mixed stratified random - fixed station design, was conducted in June 2011. Survey design and station selection methods were similar to annual surveys completed since 1995: fishing depths >100 fathoms, randomly selected stations in strata 13 and 15; fixed stations in strata 14 due to the difficulty in finding trawlable bottom; 30 minute tow length; and 2.5 knot vessel speed. Stations in strata 17 (inshore) were selected randomly at all depths having a bottom type identified as LaHave clay on Atlantic Geosciences Centre surficial geology maps.

The 2011 survey was completed by Motor Vessel *Cody & Kathryn*, which had also conducted the survey in 1995, 1998, 2009 and 2010. All surveys since 1997 were conducted using the standard trawl (Gourock #1126 2-bridle shrimp trawl and #9 Bison doors). Twice during the 2011 survey the association's new trawl and the new warps on the *Cody & Kathryn* were removed from the drum/winches and carefully inspected and adjusted as needed for break-in. Biomass/population estimates (swept area method) and bootstrapped confidence intervals (Smith 1997) were calculated using the catch/standard tow (17.4 m x 1.25 nm), i.e. the actual catch adjusted to the standard by the average measured wing spread (using NETMIND sensors) of the survey trawl during each tow and the actual distance travelled (Halliday and Koeller 1981).

The co-operative DFO-industry series, begun in 1995, used several different vessel-trawl combinations requiring comparative fishing experiments in 1996 and 1997 (Koeller et al. 1997). In order to obtain a wider range of indicator values for this series, it was extended to include DFO surveys conducted in 1982-1988, a period of low abundance in contrast to the present period of high abundance. There were no comparative fishing experiments that allowed direct intercalibration of the two survey series, consequently, catch data were only adjusted by the difference in the wing spreads of the trawls used. Wing spreads were based on the performance specifications of the trawl used for the earlier series, and from actual measurements for the latter series. However, it is probable that the trawl used during the recent series was more efficient in catching shrimp than during the 1982-1988 series, consequently, *the large differences in catch rates between the two series may be exaggerated and should be interpreted cautiously.* Since the cod end mesh size in both series was the same (40 mm) size selectivities of the two series were assumed to be the same.

The chronology of survey vessels, gear changes and comparative fishing experiments are summarised below:

1995: *Cody & Kathryn* – used vessel's commercial net
1996: *Lady Megan* II – vessel's net, comparative fishing with *Cody & Kathryn*
1997: *Miss Marie* – survey trawl (new, built by Nordsea), comparative fishing with *Cody & Kathryn*
1998: *Cody & Kathryn* – survey trawl
1999-2001: *Carmel* VI (named *Amelie Zoe* in 1999) – survey trawl
2002-2003: *All Seven* – survey trawl (built by Pescatrawl)
2004-2008: *All Seven* – survey trawl (new in 2004)
2009: *Cody & Kathryn* – survey trawl (refurbished by Capt. Schrader)
2010: *Cody & Kathryn* – survey trawl (checked by Capt. Schrader and Morgan Snook)
2011: *Cody & Kathryn* – survey trawl (new in 2011)

Gulf Vessels Catch Per Unit Effort

A CPUE index for Gulf based vessels, which have the longest history in the fishery, is calculated as a simple unstandardised mean catch/hour fished for all vessels fishing in any given year.

These are the largest vessels in the fleet and although the participating vessels (and fishing gear) have changed considerably, they have always been >65' in length, compared to the <65' Nova Scotia fleet. This is an important time series, because it spans periods of both high and low abundance of the stock. However, since fishing methods and gear have improved over the years (i.e. introduction of Nordmøre grate in 1991), it is likely that the differences in CPUEs between the period of low abundance (pre-1993) and the recent high abundances are exaggerated and should be interpreted cautiously.

Commercial Trawler (Nova Scotia Fleet) Standardised Catch Per Unit Effort

Data on catch rates were obtained from fishers' logs required from all participants and provided by DFO Maritimes Region Statistics Branch. The standardised CPUE series for 1993-2011 uses data for the 26 vessels that have fished for at least 7 of the 18-year series. CPUE data were limited to April-July inclusive, the months when the bulk of the TAC is generally caught.

A generalised linear model was used to standardise commercial CPUEs with year, month, area, and vessel as categorical components. Predicted standardised CPUE values and confidence limits for a reference vessel, month, and area were then calculated for each year using the package predict.glm (R Development Core Team 2005). The data fit best to a Gaussian distribution (lowest Akaike information criterion value).

An increase in this and the preceding indicator does not necessarily indicate increasing stock abundance, especially when coupled with a decrease in the area fished (see commercial fishing area below) or a decrease in the dispersion of the stock (see research vessel (RV) coefficient of variation (CV) below).

Research Vessel Coefficient of Variation

A measure of dispersion was calculated from survey data as the simple CV of all survey sets for each year, i.e. the standard deviation of all catches divided by the overall average weight caught. An increase in this statistic indicates increased aggregation of shrimp on the grounds.

Commercial Fishing Area

A measure of dispersion was also calculated from commercial data as the number of area units (1 minute squares) having an average catch of >250 kg per hour. With catch rates continuing to increase but survey estimates decreasing, a decrease in this index would indicate a concentration of the remaining stock in smaller areas. Interpretations of changes in this index should also take into account changes in the area of other average catch rate categories (see Figure 3), indices of abundance, and the spatial distribution of effort.

PRODUCTION

Research Vessel Age 1 Abundance

Starting in 2002, a small-meshed "belly-bag" was added to the footrope during all regular June survey sets to obtain an index of age 1 shrimp abundance. Belly-bag catches of *P. borealis* were frozen and returned to the laboratory for analysis. Abundance of age 1 shrimp was calculated by the swept area method as per the main trawl, except that wing spread was taken as 1 m, the expected width of the belly-bag when fishing. Nine years of age 1 abundance data are now available and the results were included in the traffic light analysis for the first time in 2009.

Research Vessel Age 2 Abundance

A random sample of eight pounds of shrimp (approximately 300 individuals) was collected from the catch of each survey set and frozen for detailed analysis, i.e. carapace length, individual weight, sex and egg developmental stage. Survey population estimates (numbers) were

determined by the swept area method using individual set length frequencies and weights caught, and a length-weight relationship. Survey population estimates by age group were then estimated by separating total population at length estimates from the swept area method into inferred age groups using modal analysis ("mixdist" in R). The data were assigned to six age bins which are interpreted as corresponding to ages 2-7. Modes corresponding to older ages are binned together as 5+ because the assignment of ages would be highly subjective for ages 6 and older. Fitting the data to six ages provided a highly significant fit to the length frequency distribution (Chi-square, $p<2.2e-16$) relative to either 5 (Chi-square, $p<8.0e-05$) or 7 (Chi-square, $p=0.037$) age bins.

Research Vessel Age 4 Abundance

Age 4 abundance is calculated as per age 2 above, from survey population at length estimates (swept area) and modal analysis.

On the Scotian Shelf, most age 4 shrimp are in their final year as males. This group represents shrimp that will breed as males during the survey year and will change sex the following year. Since females comprise most of the catch, the last-year males are a measure of recruitment to the fishery.

Research Vessel Spawning Stock Biomass (Females)

The SSB, or total weight of females in the population, was calculated with the swept area method from the weight of females in each set, determined by identifying females and their lengths in the detailed sample, the total catch weight, and a length-weight relationship. This estimate includes shrimp that were in the transitional stage during the survey. On the Scotian Shelf, transitional shrimp are seldom found during the fall, i.e. all transitionals complete sex change during the summer and extrude eggs during the late summer.

A clear stock-recruitment relationship has not yet been described for the Scotian Shelf, although it has been for some other pandalid stocks (Hannah 1995, Boutillier and Bond 2000). On the Scotian Shelf, a large population increase began during the late 1980s when SSBs were about 4300 mt, about 30% of those found in the late 1990s. It would, therefore, be prudent not to let the SSB decrease below 4300 mt; however, the stock increase at these SSB levels occurred at specific favourable environmental conditions (cold water temperatures and decreasing natural mortality due to predation) and negligible fishing mortalities. Consequently, this SSB should be considered as the very lowest the stock should be allowed to decline, and a more conservative value (5459 mt) is used as the lower reference point for this stock. Coincidently, this is nearly identical to the default 0.33 percentile used as the red limit for all indicators, including SSB.

Spawning stock biomass by itself is not a measure of reproductive capacity. Since fecundity is directly related to size, it should be considered in conjunction with the average size at sex transition, maximum size, and amount of fishing during the ovigerous period. In addition, multiparous females tend not to spawn every year. An index of egg production would be a useful addition to the assessment.

Size at Sex Transition (L_t)

Shrimp in transition from the male to the female are identified by the pleopod development method and their average size is calculated as overall average from all sets in the survey.

Koeller et al. (2003b) and Koeller (2006) show that size at transition is related to growth rate. It is hypothesised that an increase in growth rate, due to density dependant effects or temperature increases (Koeller et al. 2000a), results in decreases in the size at transition, maximum size, and fecundity, followed by a population decline.

Maximum Size (L_{max})

Average annual maximum size is calculated as the average of the maximum size of shrimp observed in port samples. The mean of the longest carapace length from each port sample is calculated for each fishing date. These mean values are then averaged for each month, and the monthly values are averaged for the calendar year to obtain the Traffic Light value.

The ratio of size at sex transition to maximum size was hypothesised to be constant (invariant) at about 0.8-0.9 for all stocks of *P. borealis* (Charnov and Skúladóttir 2000). This rule was shown to apply to the Scotian Shelf (Koeller et al. 2003b, Koeller 2006). Consequently, maximum size attained in the population is another growth indicator, i.e. change in maximum size is probably indicative of a change in growth rate. The relationship between L_t or L_{max} to changes in growth rate is complex due to the influence of other factors including concurrent changes in longevity and natural mortality (e.g. slower growing shrimp tend to live longer).

Predation

A predation index is calculated as the mean catch/set of all major finfish species (codes<1000) combined from the summer groundfish survey for strata which encompass the shrimp holes, i.e. strata 443-445 and 459.

This is considered an index of natural mortality. Groundfish abundance is negatively correlated with shrimp abundance on the Scotian Shelf and in most other shrimp fishing areas.

FISHING EFFECTS

Commercial Counts

Fishers determine the number of shrimp per pound (the "count") in their catches soon after they are brought aboard in order to determine the price which they will obtain from buyers, and adjust fishing practices (especially location) accordingly. This information is of economic importance and is often conveyed to other fishers or buyers before landing, so care is usually taken in obtaining and recording it. The methodology used is basic (number of shrimp in a fixed volume, often a tobacco can, that weighs about one pound), but generally agrees with more rigorous methods used by buyers. The index used here is the simple arithmetic average of all counts reported in log books for the year.

This indicator is a measure of the ease or difficulty fishers are having in "making the count," i.e. getting the best price for their shrimp. An increase in the count could indicate that a) recruitment is good and there are so many small shrimp it is difficult to avoid them or b) the population of larger shrimp is declining, or a combination of a) and b). Moreover, an increase in this indicator can be considered good (increased recruitment) or bad (growth overfishing) depending on whether it is placed in the production or fishing effects characteristic. Consequently, this indicator must be considered with others including abundance indices of the different age categories. Note that counts also change considerably during the fishing season, usually starting relatively high, decreasing to a minimum in July, and increasing thereafter, probably due to size specific changes in vertical and\or geographic distribution associated with changes in day length.

Total Exploitation Index

An overall index of exploitation rate is calculated as the total catch weight divided by the RV biomass estimated using the swept area method.

The RV biomass estimate has been shown to be underestimated by as much as 25% because of lack of coverage in shallow areas surrounding the shrimp holes; consequently, the exploitation rate is probably overestimated. This indicator is, therefore, considered an index of

exploitation. Since the survey uses a common commercial trawl with a Nordmøre grate, its selectivity is similar to commercial gear. The biomass used to estimate exploitation can be considered an estimate of "fishable biomass."

Female Exploitation Index

This is calculated as the estimated weight of females in the catch divided by the weight of females in the population from the survey, i.e. the SSB. A collaborative port sampling program that began in 1995 allows determination of the catch composition by developmental stage and size from detailed analyses as per survey samples. Samples were collected during the fishery in all areas from all fleet components including vessels <65' length over all (LOA) landing mainly in Louisbourg and vessels >65' LOA landing mainly in Arichat. The number of samples per month and area was approximately allocated in proportion to weight of landings. Catch at length was determined from a weighted length frequency and a length-weight relationship.

Female exploitation is of interest because the shrimp fishery is selective for the larger females. It can be considered one measure of the impact of fishing on the reproductive potential of the stock.

Proportion of Females in Catch

The proportion of females in the catch by weight to the total catch weight is calculated from commercial samples which identify females, lengths, and individual weights as per survey samples.

A decrease in this indicator could indicate a decrease in the number of larger shrimp in the population due to fishing removals and an increased reliance on smaller animals, i.e. possible growth overfishing and/or recruitment overfishing. It should be interpreted cautiously and in combination with other indicators, since it could also indicate good recruitment conditions and difficulty in avoiding young shrimp.

Average Size of Females in Catch

This indicator is calculated as the overall annual average size of females from port samples collected throughout the fishery.

A decrease in this indicator could indicate a decrease in the number of larger shrimp in the population due to fishing removals and an increased reliance on smaller animals, i.e. possible growth overfishing and/or recruitment overfishing.

Fishing during Ovigerous Period

This is calculated as the percent of the total catch caught during August-March, the usual period when females are carrying eggs.

Since most eggs are laid by a single age class (i.e. age 5), enough females must escape the fishery to prevent recruitment overfishing. The fishery has generally concentrated in the non-ovigerous period with most of the catch taken during May-July, however, as TACs increased, an increasing amount of the catch has been taken during the ovigerous period. This indicator should be included with SSB and size at transition when considering the population's overall reproductive capacity, since their negative effects are probably cumulative. For example, the minimum SSB of 4300 mt mentioned above would be considerably less in terms of effective reproductive capacity if most is taken before egg hatching.

ECOSYSTEM

Population Age-length Evenness

This indicator is based on the assumption that a population spread evenly across length or age classes is more resilient to environmental or fishing perturbations than one where the population is concentrated in fewer length or age classes. It is calculated from the survey population-at-length estimate as Shannon's equitability index, E_H, which is obtained from Shannon's diversity index, H. The latter is calculated from the proportion (p) of the population in each of the total number of length groups (S).

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

This indicator is placed under the ecosystem characteristic assuming that evenness is related to the population's robustness or resiliency to various perturbations within the ecosystem, but it could also have been placed under fishing effects, since fishing will remove the largest/oldest length/age classes, or production, since an even length/age distribution implies stable recruitment. On the other hand, this index will also respond to the passage of an exceptional year class through the population, which may not be a negative development if the abundance of other year classes remains relatively stable.

Research Vessel Bottom Temperatures

Shrimp survey bottom temperatures are determined throughout each shrimp survey set with a continuous temperature recorder (Vemco Ltd.) attached to the headline of the trawl and are generally consistent with temperatures from the groundfish survey. In the past, this index was calculated from July groundfish survey data as the mean bottom temperatures at depths >100 m in sampling strata (443, 444, 445, and 459) on the eastern Scotian Shelf that encompass the shrimp grounds (because it provided a longer data series). However, given inconsistencies in groundfish survey temperature recording methods and the fact that that shrimp survey temperature data series now covers 16 years, the latter is now used.

It is hypothesised that warmer water temperatures have a negative influence on shrimp populations because of the decreased fecundity associated with increased growth rates, decreased size at transition, and decreased maximum size as described above. Recent work also indicates that colder bottom temperatures increase egg incubation times resulting in later hatching times, which are closer to favourable spring growing conditions (warmer surface water and the spring phytoplankton bloom) (Koeller et al. 2009b).

Spring Sea Surface Temperatures

Sea surface temperatures (SSTs) are calculated from satellite data as average temperatures within defined rectangles encompassing the shrimp holes. Negative correlations between SSTs and lagged population estimates are common for the southern *P. borealis* stocks, including the Scotian Shelf. This may be related to water-column stability and the match-mismatch of resulting phytoplankton bloom conditions with hatching times as hypothesised by Ouellet et al. (2007). Accordingly, SSTs used were averages for a period encompassing average hatching times on the Scotian Shelf (mid February to mid March).

Research Vessel Capelin Abundance

This is calculated as the average catch/tow in numbers from the July groundfish survey in strata 443-445 and 459.

Capelin is among the most common bycatch species, both in the Scotian Shelf shrimp fishery and the June shrimp survey. Here they have been shown to increase in abundance during cold periods, which are also favourable to shrimp, and so can be considered a sympatric species

(e.g. Frank et al. 1994). Their presence can therefore be considered an indicator of conditions favourable to the production of shrimp.

Research Vessel Cod Recruitment

This is calculated as the average number of <30 cm fish/tow from the July groundfish survey in strata 443-445 and 459.

Cod abundance is generally negatively correlated with shrimp abundance for most north Atlantic stocks, including the Scotian Shelf. This is probably partly due to large scale environmental influences, such as temperature, which appear to have opposite effects on cod and shrimp population dynamics, as well as a trophic effect of cod predation on shrimp. Restricting this indicator to juvenile cod may therefore decrease the influence of predation and have some predictive value for shrimp abundance.

Research Vessel Greenland Halibut Recruitment

This is calculated as the average number of <30 cm fish/tow from the July groundfish survey in strata 443-445 and 459.

Greenland halibut is a cold water species whose abundance is often positively correlated to shrimp abundance. However, it should be noted that Greenland halibut are also known predators of shrimp, and so an increase in this indicator is both positive and negative. Restricting this indicator to juvenile halibut may decrease the influence of predation and have some predictive value for shrimp abundance.

Research Vessel Snow Crab Recruitment

This is the stratified random abundance index for pre-recruits calculated for the snow crab assessment from annual crab surveys in southeastern Nova Scotia. Like Greenland halibut and capelin, snow crab is a cold water species that is often positively correlated with shrimp abundance.

TRAFFIC LIGHT SUMMARY

Individual traffic light indicators were summarised using simple averaging. Each indicator is given a value according to its colour, i.e. green = 3, yellow = 2, and red = 1, and an average is calculated. This average is assigned a "summary colour" according to limits determined by the probability distribution of possible outcomes, i.e. the limits between red, yellow, and green are set so that each of the three summary colours has an equal probability of being assigned in a random set of individual indicator colours/values. The DFO Maritimes Regional Science Advisory Process (SAP) review committee has emphasised that the summary is difficult to interpret and should not be the primary consideration in the advice, because issues such as weighting of indicators and harvest rules associated with any particular summary have not been resolved.

BYCATCH

Gulf and Nova Scotia fleet trawl configurations including the use of the Nordmøre grate continue to ensure low total bycatch (2.71%) by weight (Table 7). It is noteworthy that this value is very likely over-estimated due to the minimum 1 kg weight recorded by the observers (e.g. a single sand lance would be recorded as 1 kg despite weighing only a few grams). However, total bycatch by weight from this summary (Table 7) is approximately 50% higher than was summarised in 2010 (Hardie et al. 2011), which appears to be due to the addition of observer coverage in SFA 13, where high bycatch of herring (1.97%) and capelin (3.45%) contributed to a total bycatch by weight of 7.3%, much higher than in the other areas. Nonetheless, the

Scotian Shelf mobile shrimp fishery currently poses little risk in terms of bycatch amount or species-composition.

RESULTS AND DISCUSSION

PRECAUTIONARY APPROACH

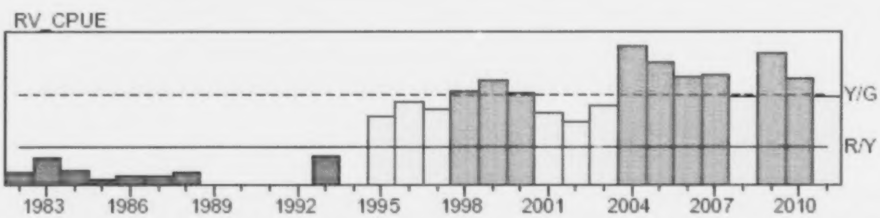
Spawning stock biomass and female exploitation indices are reported in the Traffic Light (below), but these indices also define stock and removal reference points for Scotian Shelf shrimp. In this context, it is worth reiterating that SSB itself is not a measure of reproductive capacity. Because the relationship between fecundity and size, and the dynamic range of shrimp size in response to fluctuations in density, temperature and growth rate, it is important to carefully consider the "Auxiliary Data" provided by the Traffic Light Indicators when interpreting the reference points depicted in Figure 1. Koeller et al. (2000a) hypotheses that increases in growth rate due to density dependent effects or temperature increases can result in decrease in size at transition, maximum size and fecundity, followed by a population decline. Another index of particular relevance in this context is the proportion of the TAC taken during the ovigerous period, because provides a metric of the proportion of the SSB that will be removed from the population before they can reproduce.

TRAFFIC LIGHT ANALYSIS

Input data for the traffic light analysis are given in Table 3. These data are graphed in the uncaptioned figures immediately following the indicator headings in the section below.

ABUNDANCE

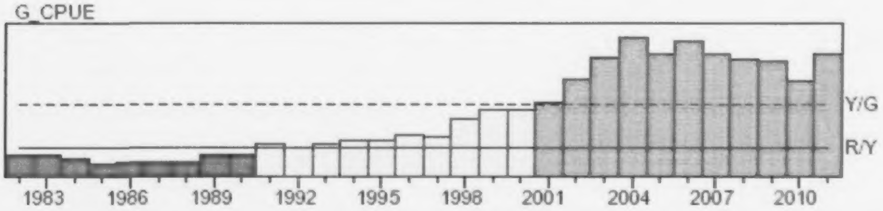
Research Vessel Abundance Index



The stratified survey estimate for 2011 (representing a biomass of 30,510 mt using the swept area method) decreased by 18% for the second consecutive year from what was its second highest estimate on record in 2009 (Figure 4; tables 4, 6). The biomass estimate for SFA 13 increased by 68% but remains lower than other SFAs. Biomass estimates for SFAs 14 and 15 decreased for the second consecutive year (9% and 11%, respectively), as it did in stratum 17 (inshore), where biomass decreased by 48%, following an increase in 2010. The distribution of survey catches during the last two years is shown in Figure 5. This year's decline in the survey biomass estimate was consistent with concomitant declines in the commercial CPUE index (Figure 6, top).

Interpretation: Density dependent effects (slow growth, larger body size, delayed sex-transition) of cohorts that followed the very large 2001 year class helped to bolster biomass after the die-off of the 2001 year class in 2010. The further decrease in biomass in 2011 is attributable to the end of these "following" year classes, and their replacement by smaller-bodied and less abundant year classes.

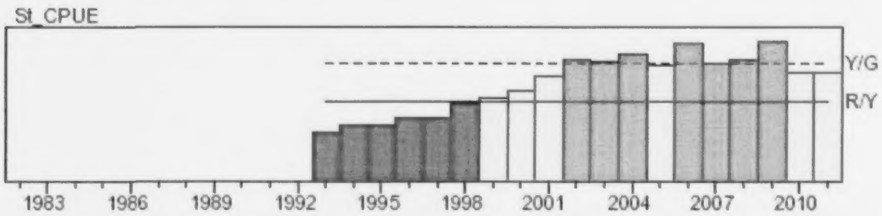
Gulf Vessels Catch Per Unit Effort



The unstandardised Gulf Vessel CPUE showed an increasing trend during the late 1980s to 2004 before stabilising at a relatively high level since that time. The value increased in 2011.

Interpretation: The increase in this CPUE indicator is consistent with the prediction (Hardie et al. 2011) of increases in CPUE as the strong 2007-2008 year classes recruit fully to the fishery in 2012-2013, although other indicators of biomass suggest otherwise. Gulf vessels fish earlier in the year than the survey or the Nova Scotian fleet (standardised CPUE), which lessens the expectation that these three indicators would always show similar trends. In 2011, Gulf vessels reported particularly good catches in the late-winter and early spring. By contrast, some of the most productive vessels in the Nova Scotian fleet suffered from poor catches, at least some of which was attributed to gear problems.

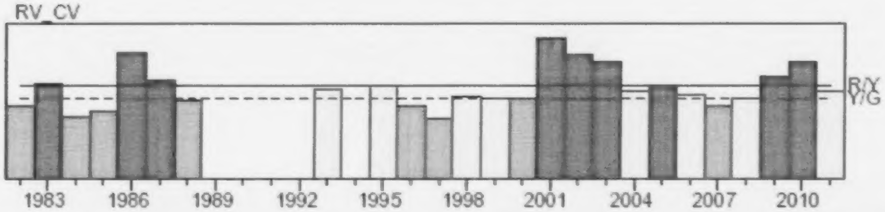
Commercial Trawler Standardised Catch Per Unit Effort



The standardised CPUE indicator remained stable for 2011 at a relatively high level. This series follows a similar pattern to the Gulf series, showing an increasing trend until 2004, fluctuations at a high level since, and a downturn for 2010 that is consistent with the other CPUE-based indicators. There have been two divergences between commercial CPUEs and the shrimp survey (Figure 6, top), i.e. 2000-2003, and 2005-2008. The first divergence was attributed to distributional changes associated with the demise of the large 1995 year class. The second divergence appears to be, at least in part, due to problems with the survey trawl (Koeller et al. 2011).

Interpretation: The maintenance of relatively high catch rates for all fleet sectors suggests that shrimp remain relatively abundant. Temporal differences in fishing effort and anecdotal reports of gear problems for some important Nova Scotian vessels early in the season are factors that can lessen the expectation of consistent patterns between catch rate indices.

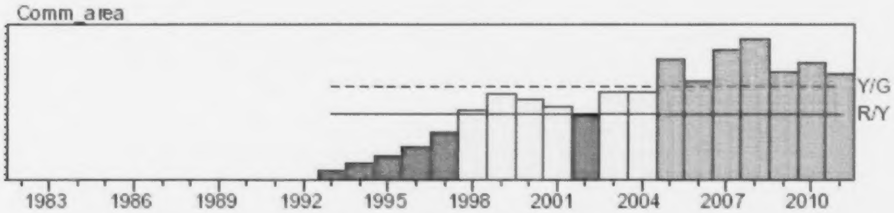
Research Vessel Coefficient of Variation



After increasing for the past three years, the survey measure of dispersion (overall CV) decreased in 2011 (Figure 7).

Interpretation: The return of this indicator to a lower value is unexpected during a period of biomass downturn, when the resource might be expected to become more aggregated on the fishing ground.

Commercial Fishing Area

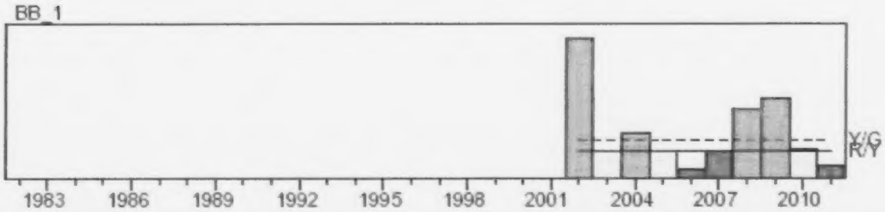


The area with commercial catch rates >250 kg/hour remained high in 2011. This indicator must be considered with the areas of other catch rates in order to interpret changing distribution and dispersion patterns of the resource. The >250 kg/hour area increased since the beginning of the series until 1999, when it began to decrease, presumably because shrimp from several strong year classes formed dense concentrations in a smaller area during the biomass decrease. Consistent with this interpretation, the area with catch rates >150 kg began to decrease in 1997, while the interval with the highest catch rates (>450) continued to increase (Figure 3, top). Also, areas of intermediate catch rates (151-250, 251-350, and 351-450 units) peaked in sequence (Figure 3, bottom) as the resource increased in density. After 2001 the area of highest concentration (>450) continued to increase, while all other areas remained relatively small. Currently, the area of highest concentration continues to decrease, while areas of low or intermediate density are fairly stable.

Interpretation: The continued decline of the area of highest density coupled with relatively stable areas of low and intermediate density, are characteristic of a declining, but still relatively abundant resource.

PRODUCTION

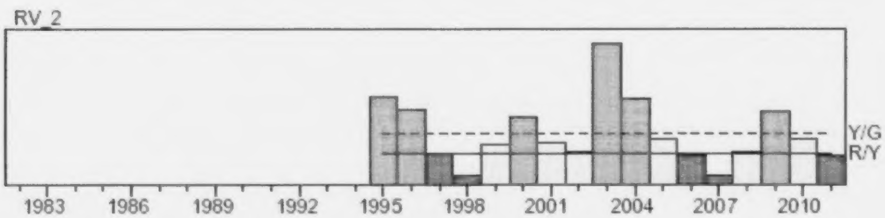
Research Vessel Belly-bag Abundance at Age 1



The belly-bag index declined by more than 100% in 2011, following a greater than 60% decline in 2010. This index shows considerable dynamic range despite only 10 years of data. It correctly predicted the strength of the 2001 year class at age 1 in 2002, two years before it began to show up in commercial catches, and as many as five years before it was fully recruited to the fishery (figures 9,10; Table 5). The apparent strength of the 2007 and 2008 year classes as 1 year olds in the 2008 survey supports the hypothesis that a pulsed recruitment pattern has been established, similar to the snow crab stock in the same area but with a cycle of six to seven years, about equal to the species life cycle. If these year classes hold up as strong, this would make three such pulses since the modern fishery began, i.e. associated with the 1994-1995, 2001, and 2007-2008 year classes. The appearance of recruitment cycles of different lengths provides evidence that some form of a stock recruitment relationship exists, i.e. strong year classes result in large spawning stocks, resulting in strong year classes.

Interpretation: The continued steep decline in the belly-bag index is consistent with declines in SSB during the lag until full recruitment of the 2007-2008 year class. It is notable that the spring SST was the second highest on record. High temperatures are known to negatively influence shrimp recruitment (see below).

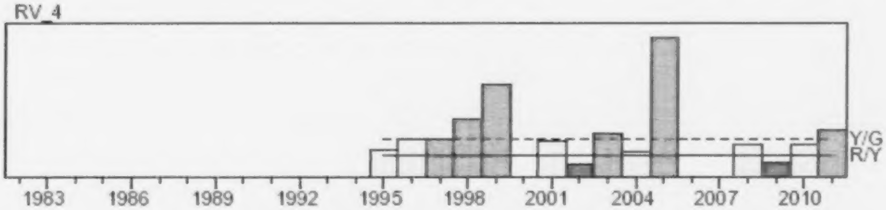
Research Vessel Abundance at Age 2



The index of age 2 shrimp decreased in 2011 for the second consecutive year.

Interpretation: Although the utility of the belly-bag index for predicting age 2 abundance has been somewhat equivocal in past years, the decline in the index of age 2 abundance in 2011 is consistent with the decline in the bell-bag index in 2010 (Table 5).

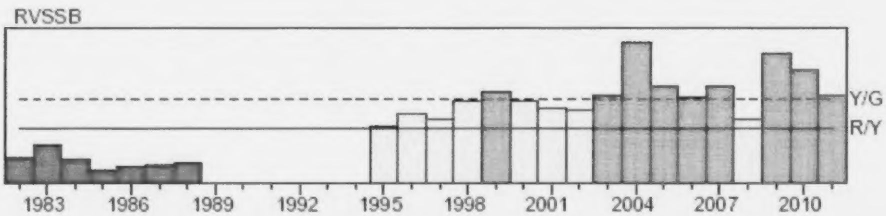
Research Vessel Abundance at Age 4



The abundance of age 4 shrimp increased from below average in 2004 to the highest on record in 2005, reflecting the recruitment of the strong 2001 year class to what usually is the oldest male age group in the population. In 2006 and 2007, this age (2002-2003 year classes) could not be distinguished from the large mode attributed mainly to the 2001 year class. A similar situation had previously occurred in 2000, following the large 1995 year class (Table 5; Figure 11). In 2008 and 2009 the 4 year olds were poorly distinguished but were estimated at below average, indicating that there were relatively few age 4 males to replace the females from the 2001 year class. Changes in this indicator also reflect the apparent cyclical recruitment pattern seen with the ages 1 and 2 indicators above. The abundance of age 4 shrimp increased for the third consecutive year in 2011 (Table 5).

Interpretation: The increase in age 4 shrimp in 2011, reflects the abundant 2007 year class in their last year as males (usually), and is expected to provide good recruitment to the female population next year.

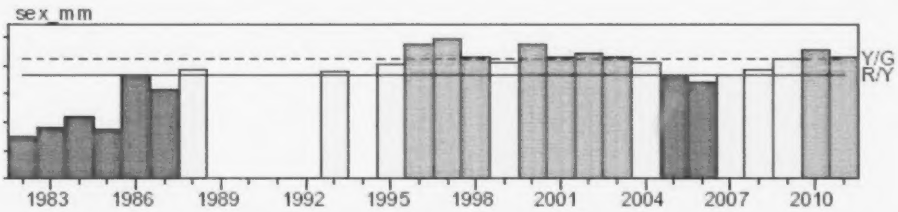
Research Vessel Spawning Stock Biomass (Females)



Although SSB decreased slightly this year, it remains in the healthy zone, above the URP for the precautionary approach (Figure 12, top).

Interpretation: This decrease in SSB was predicted based on the expectation of a delay in the recruitment of the 2007-2008 year classes to the SSB in 2012-2013. The relatively high SSB index should be interpreted with caution. The index has been declining since 2009, and with the exception of the moderately abundant 2007-2008 year classes, there is little promise of strong recruitment to the adult population after 2013. Secondly, decreases, albeit minor ones, in most shrimp size indices, suggest that the fecundity of females is also decreasing. This, coupled with the increased proportion of the TAC taken during the ovigerous period in recent years, suggests that juvenile recruitment is unlikely to improve from recent low values. These factors have the potential to lead to population decline (Koeller et al. 2000).

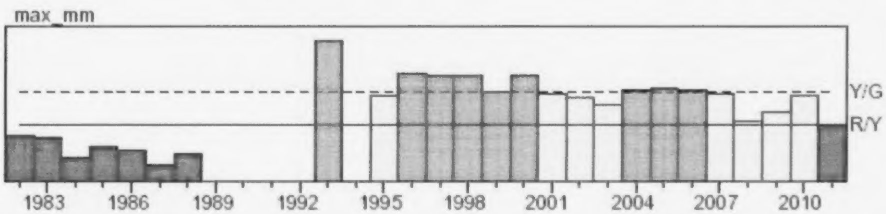
Average Size at Sex Transition (L_t)



This indicator decreased slightly for the first time since it began increasing in 2006 (Figure 13, top).

Interpretation: Delayed sex-transition occurs during periods of high population density, and results in extra years of growth, which in turn results in the production of larger females. This is consistent with increases in this value throughout the high-density period associated with the recruitment and passage of the 2001 year class through the fishery and with the current decrease given the ongoing population downturn. Continued downturns in this index are a cause for concern because the strong relationship between female size and fecundity could limit recruitment for a given SSB.

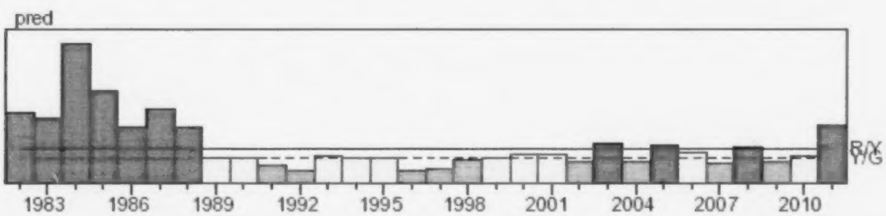
Average Maximum Size (L_{max})



Maximum size decreased in 2011 after three years of increase (figures 13 (top), 14).

Interpretation: In general and over the long-term, maximum size tends to track size at transition. The larger size of sex transition of the large 2001 year classes and the abundant late-maturing ages 4+ males reported in 2009 continues to result in larger several years of increasing shrimp sizes. As described above, a decrease in this value is expected in this period of population downturn and has the potential to limit recruitment.

Predation

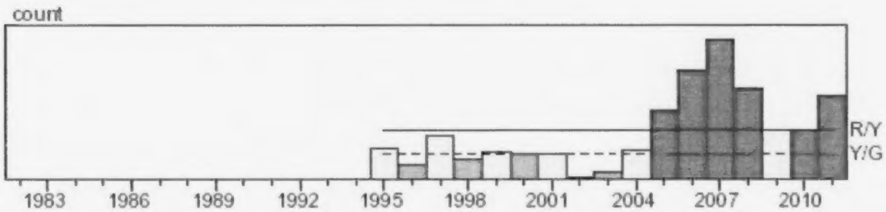


After two decades of very low values, the 2011 groundfish abundance index rose sharply to a level similar to those observed in the early 1980s when the shrimp population was low.

Interpretation: Natural mortality (M) due to predation is likely to be higher than it has been in nearly two decades.

FISHING IMPACTS

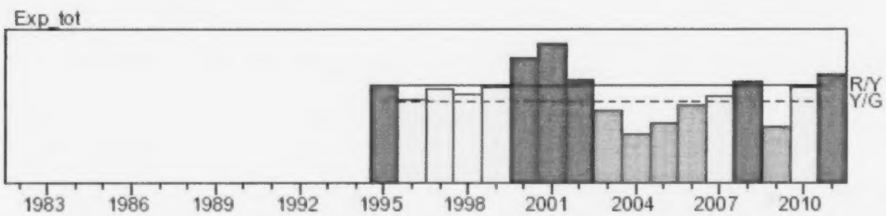
Commercial Counts



The commercial count increased in 2011 (Figure 14). The sharp rise to a peak in 2007 was associated with the maximum catchability of the 2001 year class which has dropped since that time as this abundant year class moved through the population as large, late-maturing females.

Interpretation: The period of low counts associated with the remnants of the 2001 and succeeding late-maturing age classes appears to have passed.

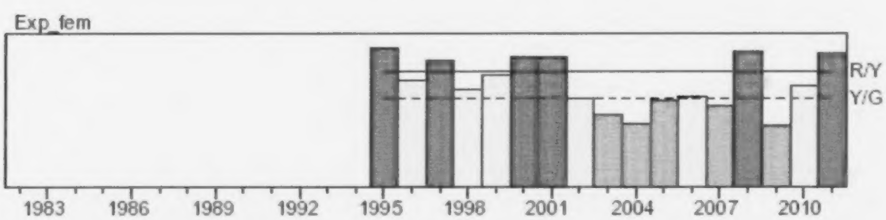
Exploitation Index



Assuming that the TAC is taken in 2011, the total exploitation index increased (Figure 12, bottom).

Interpretation: The increase in the exploitation index for 2011 reflects the reduced biomass (18%) despite the decrease in the TAC (8%).

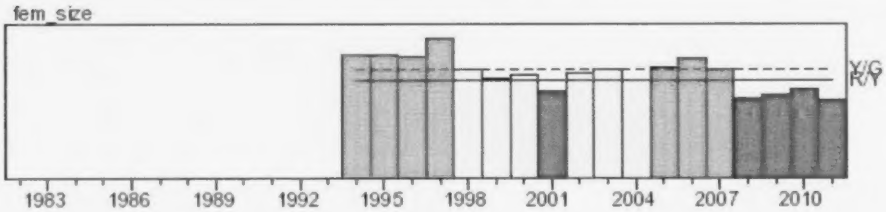
Female Exploitation Rate



Female exploitation rate increased in 2011 to a value above the long-term average (Figure 12, bottom) and slightly above the removal reference point of 20% of the SSB (Figure 1).

Interpretation: The high value for 2011 reflects the relatively high TAC and decrease in female biomass because the abundant 2007-2008 year class has not yet fully recruited to the fishery.

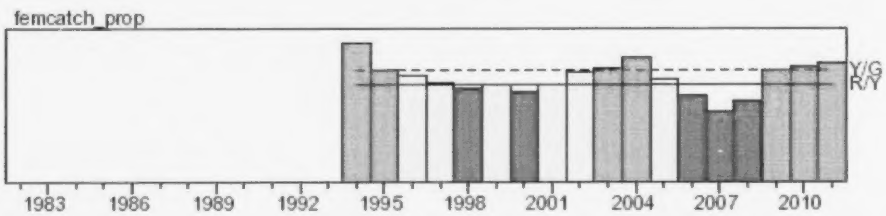
Mean Size of Females in Catch



The average size of females in the catch decreased slightly and has remained at a low level for the past four years.

Interpretation: The average size of females in the catch has decreased from the early years of the fishery as the larger animals were selectively removed from the population. The large decrease in 2008 was due to the recruitment of the slow-growing 2001 year class as females. The recent and current stabilization at a lower level is consistent with the end of the 2001 year class.

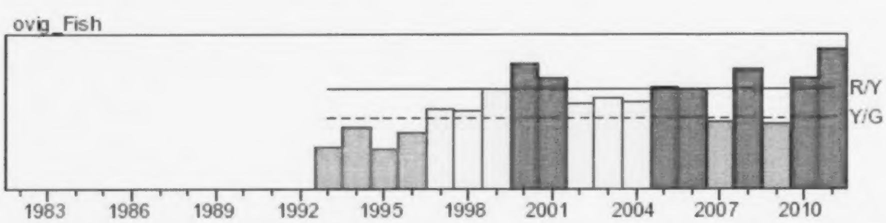
Proportion of Females in Catch



The proportion of females in the catch decreased from 2004 to 2006 and has increased since (Figure 14).

Interpretation: The proportion of females in the catch decreased between 2004 and 2006 due to the increase in the proportion of 2001 year class males. The increase in 2007-2010 was due to the sex change and recruitment to the female population of this year class and the delayed sex-transition of abundant 4+ males observed in 2009. Given this year's decreases in shrimp size indicators (above), this small increase in the proportion (by weight) of females in the catch reflects the relatively high SSB relative to less strong following year classes.

Fishing during Ovigerous Period



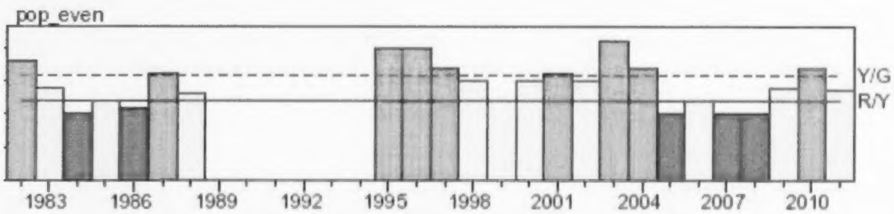
Fishing during the ovigerous period increased significantly after the early years of the fishery due to the larger TACs and the longer time required to catch them. This year, if the remainder of the TAC is taken (which is likely), fishing during the ovigerous period will be the highest on record. Figure 14 (top) shows higher than average catch in March (2011) followed by lower than average catch throughout the spring, summer and early fall (the non-ovigerous period). The

lower-than-average catches during the non-ovigerous period have left a larger proportion of the TAC to be caught in November-December than is usual. The contributions of market conditions or sharing of fishing grounds with the snow crab fishery to this temporal shift in effort are not known. However, rapid declines in CPUE to below-average levels in June and July are shown in Figure 14 (bottom), and may explain the concomitant declines in effort (Figure 13, bottom) and catch (Figure 14, top) during the non-ovigerous summer months.

Interpretation: Fishing during the ovigerous period has the potential to impact population reproductive potential by removing ovigerous females before their eggs have hatched. This was less of a concern in recent years as the 2001 year class appeared to be changing sex over several years and spreading its large reproductive potential over a wider time period than normal. If market conditions and/or sharing of the fishing grounds with snow crab fishers are contributing factors, efforts should be made to mitigate the degree to which this results in the harvest of as large a proportion of the TAC during the ovigerous period as has been seen in recent years.

ECOSYSTEM

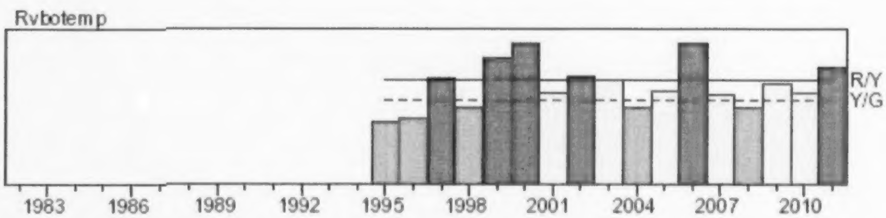
Population Age-length Evenness



Population evenness was high at the beginning of the survey series in 1995 when the fishery was relatively new (it first attained the TAC only in 1994). It declined in the late 1990s as the large 1994-1995 year classes dominated the population, and has been very low during the last four years as the 2001 year class dominated, with values comparable to those seen during the low population levels in the mid 1980s. This could represent an unstable situation leading to recruitment pulses, population fluctuations, and possible "boom and bust" fishery scenarios. This index increased in 2009 and again in 2010, but decreased slightly in 2011 (to match the 2009 value).

Interpretation: The 2011 value and relative stability of this index is consistent with a population composed of several year classes that is likely to be relatively resilient to environmental perturbations, although the decrease this year reflects the small recruiting year classes after the 2008 year class.

Research Vessel Bottom Temperatures



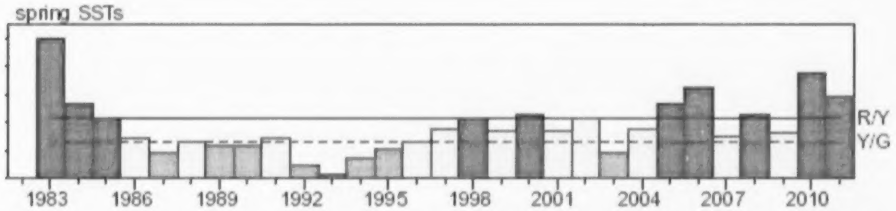
For some northern shrimp stocks near the southern limits of the species' range, abundance is negatively correlated with water temperatures. On the eastern Scotian Shelf, the large

population increase that occurred from the mid 1980s to the mid 1990s is associated with colder surface and bottom water temperatures. This is at least partly because colder temperatures increase the length of the egg incubation period, resulting in later egg hatchings that are closer to the spring phytoplankton bloom and warming of the surface layers where larvae feed and grow. Large fluctuations in bottom water temperatures may also be associated with the cyclical recruitment pattern experienced since the early 1990s (i.e. 1993-1995, 2001 and 2007-2008 year classes).

Bottom temperatures on the shrimp grounds were relatively high during the 1980s, when the shrimp population was low, and it was low during the population increase of the 1990s. Higher temperatures preceded the population downturn in 2001-2003 and the low belly-bag index values for 2006-2007. Bottom temperatures during the shrimp survey increased in 2011 (Figure 17).

Interpretation: Colder temperatures in 2007-2008 may have helped larval survival, as measured by belly-bag results, by increasing the incubation period, bringing hatching times closer to the spring bloom and vernal warming of surface waters, conditions favourable for larval growth and survival. Similarly, the warmer temperatures in 2005, 2006 and 2009 are consistent with the low belly-bag index results in 2006, 2007 and 2010, respectively. The high value of this index for 2011 coupled with the high value for spring SST (below) contributes to the expectation of poor recruitment of the 2010 and 2011 year classes.

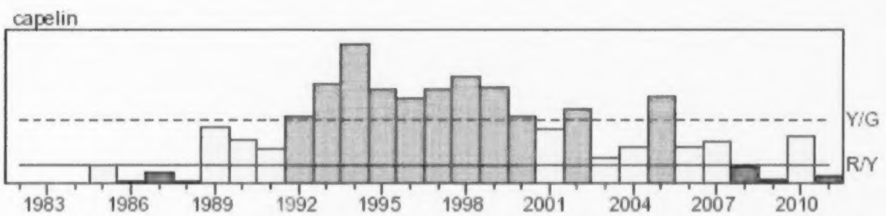
Spring Sea Surface Temperatures



The spring SST index decreased in 2011 (Figure 17), but remains higher than the long-term average. At the southern limits of distribution (Gulf of Maine), surface temperatures are inversely related to shrimp abundance with a lag of four to five years. On the Scotian Shelf, the below average temperatures prevalent during the late 1980s and early 1990s may have facilitated the high abundances in the mid to late 1990s associated with the strong 1994-1995 year classes. However, at least one exceptional recruitment event occurred recently (2001) despite relatively high SSTs.

Interpretation: Spring surface temperatures remained high in 2011, while shrimp survey bottom temperatures also increased, which could have a negative effect on recruitment in 2012, and would be a concern for the shrimp stock if the trend continues.

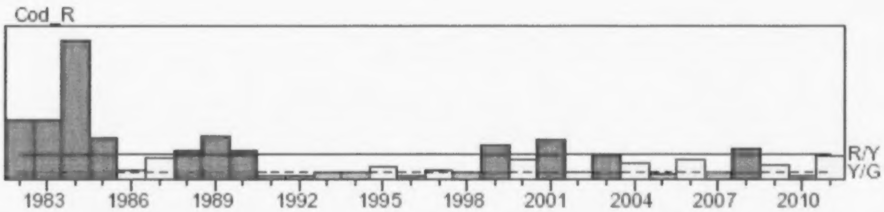
Research Vessel Capelin Abundance



During the last 10 years, capelin abundance has been lower on average than the relatively high values between 1993 and 1999, and was especially low (near those of the 1980s when shrimp abundance was low) in 2008-2009. Capelin abundance decreased sharply in 2011.

Interpretation: The low index for 2011 for this species suggests that recent/current environmental conditions are not favourable for sympatric cold water species such as capelin and shrimp.

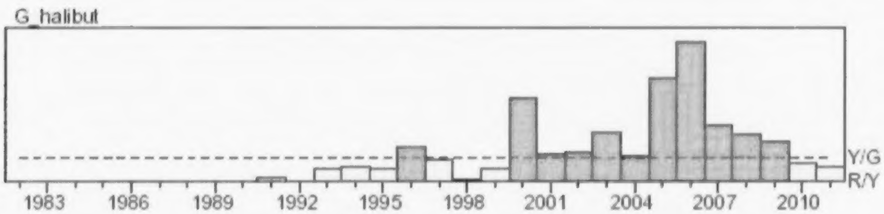
Cod Recruitment



Cod recruitment (<30 cm) increased in 2011, but still remains well below values seen in the 1980s.

Interpretation: Natural mortality of shrimp due to cod predation is likely to remain low, although this result is inconsistent with very high 2011 value for the predation index (above).

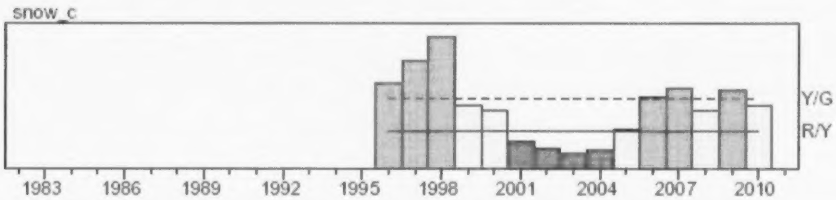
Greenland Halibut Recruitment



Greenland halibut <30 cm have been abundant on the eastern Scotian Shelf in the past decade, but have been decreasing during the last five years. This species was rarely found during the warmer period of the 1980s when shrimp and capelin were also low in abundance. Note that the relationship of the shrimp resource to this indicator is ambivalent, since Greenland halibut are also known predators of shrimp.

Interpretation: The decreasing trend for this index over the past five years is consistent with the low value for capelin and suggests that recent/current environmental conditions are not favourable for sympatric cold water species such as Greenland halibut, capelin and shrimp.

Snow Crab Recruitment[2]

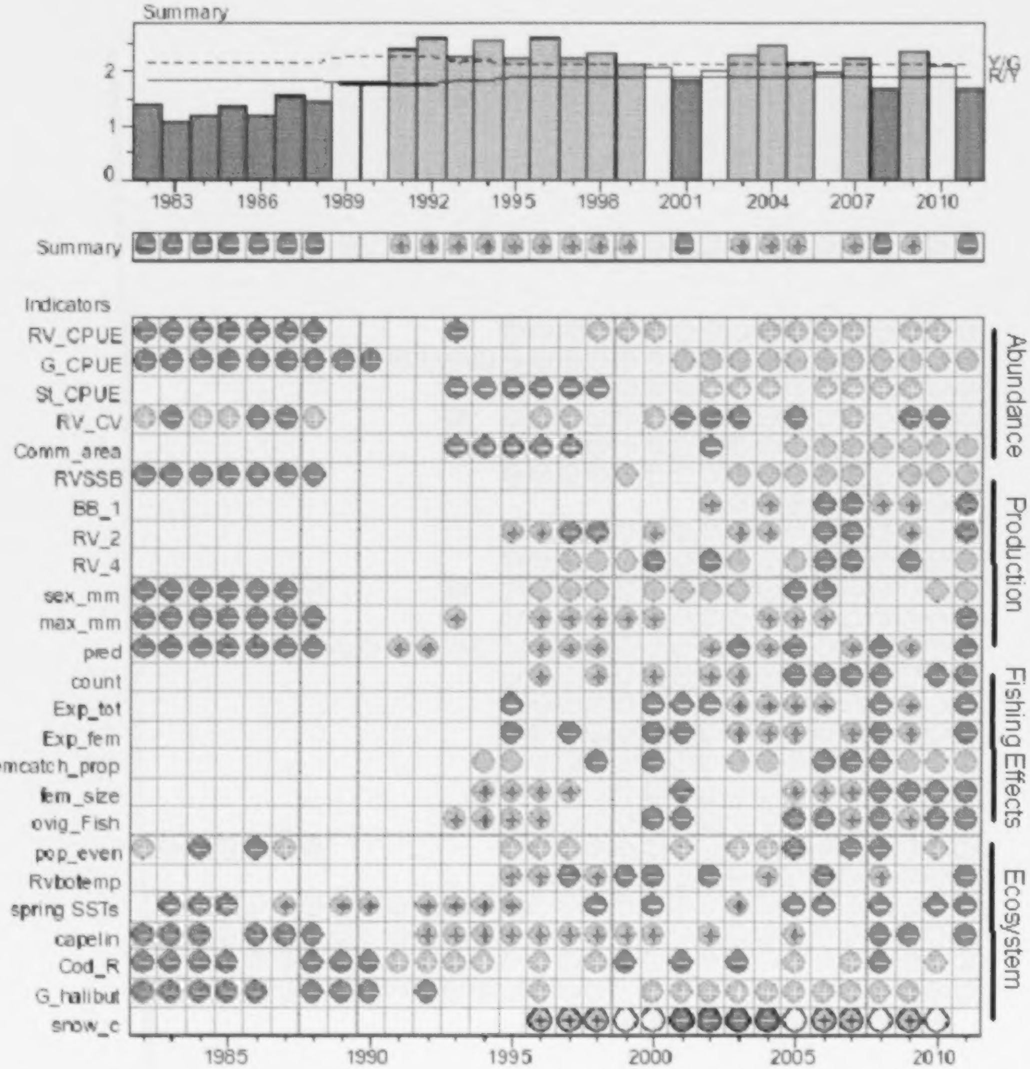


The male pre-recruit index from the snow crab survey off southern Cape Breton has been high since 2006. Snow crab abundance, as with Greenland halibut and capelin, tend to track shrimp abundance in the long-term, however, snow crab have considerably longer longevities and population cycles.

Interpretation: The decrease in snow crab recruitment from 1999-2004 has reversed. The recruitment index declined slightly in 2010, but the 2011 value is not yet available. The pulsed recruitment pattern seen in this and the shrimp populations may have similar causes. Since the cycles differ in length between these species, their cause is probably not entirely environmental, but may be driven, at least in part, by the fisheries.

[2] Value for 2011 not available.

TRAFFIC LIGHT SUMMARY

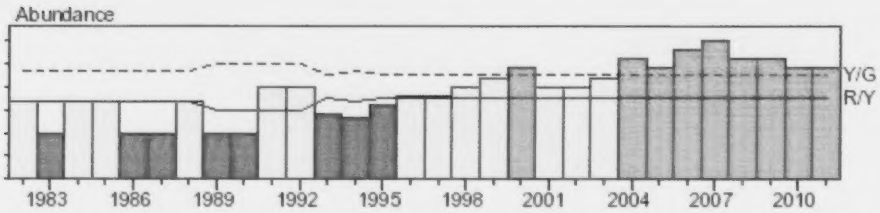


Precautionary Note: The overall summary and characteristic summary values are derived by a simple averaging process which does not account for complex interactions between indicators which may be occurring. Consequently, even the interpretation of individual indicators must be approached cautiously with regard to their relationship to stock health. Their placement within characteristics is also open to interpretation.

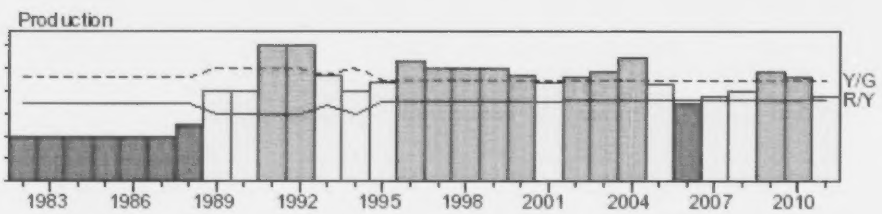
The summary indicator for 2010 decreased from green to yellow after the complete 2010 data were updated from all sources. In 2011, based on complete survey data and partial commercial data, the summary indicator declined further from yellow to red. In general, the abundance characteristics remained quite favourable, while the Production (green to yellow), Fishing Effects (red to lower red) and Ecosystem (green to red) characteristics became much less favourable.

The Abundance characteristic has remained favourable (green) for the last eight years due to the influence of the commercial CPUE indices which remained strong throughout the downturn

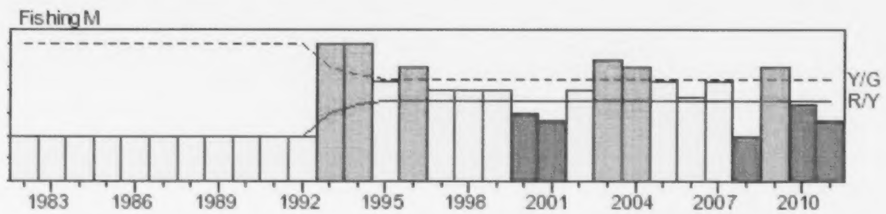
in the survey index from 2005-2008. In 2011, the downturn in the survey CPUE index was offset by a stable or increasing commercial CPUEs and improvements in the CV of survey catches and relative stability in the area of moderate commercial catch rates.



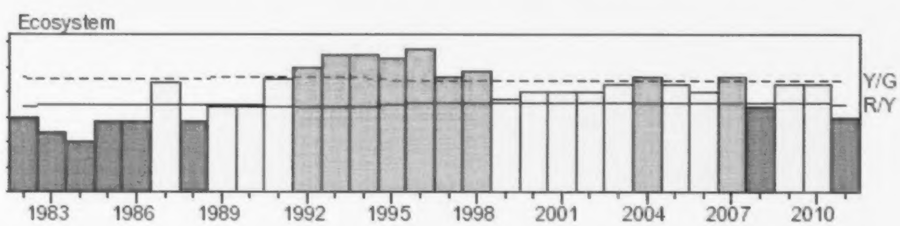
The Production characteristic became less favourable in 2011 due to declines in the abundance of age 1 (belly-bag) and age 2 shrimp, as well as decreases in indices of shrimp size and an increase in predator abundance. However, SSB remains at a healthy level and the abundant age 4 shrimp are expected to recruit to the female portion of the population in 2012).



When updated with complete 2010 data, the Fishing Effects characteristic changed from yellow to red, and has further declined to a more severe level of red in 2011. Most significantly, the index of female exploitation for 2011 met (and slightly exceeded) the precautionary approach removal reference, and the expected proportion of the TAC taken during the ovigerous period is the highest on record. Changes in most other indicators are minor, and mostly reflect high natural mortality of the late-maturing age-classes that followed the 2001 year class.



The Ecosystem characteristic changed from green to red because of unfavourable (high) temperature indices and low indices of sympatric species abundance.



SOURCES OF UNCERTAINTY

DFO-industry shrimp survey results are associated with high variances and biases associated with survey gear changes. Spatial and temporal variability in the distribution of shrimp is a source of uncertainty with regard to the accuracy of survey estimates; the survey is conducted consistently during the first 10 days of June to try to mitigate this effect. In 2007-2008, problems with NETMIND distance sensors and data logging required use of historical average instead of actual wing spread data to calculate swept areas and abundance. The trend in commercial catch rate has not always been consistent with the trend in the shrimp survey index; the possible reasons for these divergences have been discussed previously. Given the inability to accurately age shrimp, modal groups are assigned to age classes, a process that is somewhat subjective, particularly for larger individuals. Growth rates can decrease dramatically due to density dependence, as happened with the strong 2001 year class. Consequently, recruitment to the fishery will be delayed and spread over a longer time period. Unforeseen changes in the ecosystem (e.g. predators), and the environment (e.g. temperature) together increase the difficulty of making long-term projections.

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TABLES

Table 1. Total allowable catches (TACs; trawls) and catches (trawls and traps), in metric tonnes (mt) from the eastern Scotian Shelf shrimp fishery (SFAs 13-15), 1980-2011.

Year	TAC Trawl	TAC Trap	Trawl Catch SFA 13	Trawl Catch SFA 14	Trawl Catch SFA 15	Trawl Catch Total	Trap Catch	Total Catch
1980	5021	-	491	133	360	984	-	984
1981	-	-	418	26	10	454	-	454
1982	4200	-	316	52	201	569	-	569
1983	5800	-	483	15	512	1010	-	1010
1984	5700	-	600	10	318	928	-	928
1985	5560	-	118	-	15	133	-	133
1986	3800	-	126	-	-	126	-	126
1987	2140	-	148	4	-	152	-	152
1988	2580	-	75	6	1	82	-	82
1989	2580	-	91	2	-	93	-	93
1990	2580	-	90	14	-	104	-	104
[1]1991	2580	-	81	586	140	804	-	804
1992	2580	-	63	1181	606	1850	-	1850
[2]1993	2650	-	431	1279	317	2044	-	2044
[3]1994	3100	-	8	2656	410	3074	-	3074
1995	3170	-	168	2265	715	3148	27	3175
1996	3170	-	55	2299	817	3171	187	3358
1997	3600	-	570	2422	583	3574	222	3797
1998	3800	-	562	2014	1223	3800	131	3931
1999	4800	200	717	1521	2464	4702	149	4851
2000	5300	200	473	1822	2940	5235	201	5436
2001	4700	300	692	1298	2515	4505	263	4768
2002	2700	300	261	1553	885	2699	244	2943
2003	2700	300	612	1623	373	2608	157	2765
2004	3300	200	2041	755	376	3172	96	3268
2005	4608	392	1190	1392	1054	3636	9	3645
2006	4608	392	846	1997	1111	3954	32	3986
2007	4820	200	267	2633	1678	4578	4	4582
2008	4912	100	349	2703	1265	4317	4	4321
2009	3475	25	298	2450	727	3475	2	3477
2010	4900	100	280	1846	2454	4580	1	4581
[4]2011	4432	168	123	2350	1217	3690	1	3691
[5]2011	4432	168	148	2822	1462	4432	22	4454

[1] Nordmøre separator grate introduced.
[2] Overall TAC not caught because TAC for SFA 14 and 15 was exceeded.
[3] Individual SFA TACs combined.
[4] Current year to date (November 8, 2011).
[5] Current year prorated to total trawl TAC.

Table 2. Number of active vessels and total licences (in brackets) for the eastern Scotian Shelf shrimp fishery.

	Trap	Trawl	
Year	Scotia-Fundy[1]	Scotia-Fundy[2]	Gulf[3]
1995	4	24(23)	6(23)
1996	9(17)	21(24)	6(23)
1997	10(17)	18(23)	6(23)
1998	15(26)	17(28)[4]	10(23)[5]
1999	15(22)	19(28)[4]	10(23)[5]
2000	12(21)	18(32)[6]	10(23)[5]
2001	10(28)	18(28)[4]	10(23)[5]
2002	10(14)[7]	15(23)	6(23)
2003	9(14)	14(23)	5(23)
2004	6(14)	14(23)	6(23)
2005	2(14)	20(28)[8]	7(24)[9]
2006	5(14)	18(28)	7(24)
2007	2(14)	20(28)	7(24)
2008	1(14)	18(28)	7(24)
2009	1(14)	17(28)	6(14)[10]
2010	3(14)	18(28)	7(14)
2011	7(14)	16(28)	5(14)

[1] All but one active trap licences are vessels <45'. They receive about 8% of the TAC.
[2] These vessels receive about 70% of the TAC according to the management plan. Inactive NAFO 4X licences (15) not included in total.
[3] All licences 65-100' length over all (LOA). Eligibility to fish in Scotia-Fundy for about 23% of the TAC.
[4] Temporary allocation divided among 5 vessels.
[5] Temporary allocation divided among 4 vessels.
[6] Temporary allocation divided among 9 licences.
[7] Nine (9) licences were made permanent for 2002. The reduction in the total number of trap licences is due to cancellation of some non-active exploratory licences.
[8] Five (5) temporary licences made permanent.
[9] One (1) temporary licence made permanent.
[10] The previously reported number of licenses included (10) that were invalid for a number of reasons. The number of valid licenses was updated in 2009.

Table 3. Input data for traffic light analysis.

Indicators	RV_CPUE	G_CPUE	St_CPUE	RV_CV	Comm_area	RVSSB	BB_1	RV_2	RV_4	sex_mm	max_mm	pred	count	Exp_tot	Exp_fem	femcatch_prop	fem_size	ovig_fish	pop_even	Rvbotemp	spring SSTs	capelin	Cod_R	G_halibut	snow_crab
Action	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile	Pctile
Indirect																									
Rule	Abundance (production == red) +																								
Direct																									
Overwts	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Maxwts	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Level_YG	0.66	0.66	0.66	0.33	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.33	0.33	0.33	0.33	0.66	0.66	0.33	0.66	0.33	0.33	0.66	0.33	0.66	0.66
Level_RY	0.33	0.33	0.33	0.66	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.66	0.66	0.66	0.66	0.33	0.33	0.66	0.33	0.66	0.66	0.33	0.66	0.33	0.33
Characteristics	Polarity																								
Abundance	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Production	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Fishing M	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0
Ecosystem	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1

Year	RV_CPUE	G_CPUE	St_CPUE	RV_CV	Comm_area	RVSSB	BB_1	RV_2	RV_4	sex_mm	max_mm	pred	count	Exp_tot	Exp_fem	femcatch_prop	fem_size	ovig_fish	pop_even	Rvbotemp	spring SSTs	capelin	Cod_R	G_halibut	snow_crab
1982	34.50	128.00	NAN	65.54	NAN	5040.65	NAN	NAN	NAN	21.46	28.18	179.29	NAN	NAN	NAN	NAN	NAN	NAN	0.81	NAN	NAN	0.00	2.38	0.00	NAN
1983	71.50	127.70	NAN	86.01	NAN	7323.05	NAN	NAN	NAN	21.80	28.13	164.05	NAN	NAN	NAN	NAN	NAN	NAN	0.77	NAN	2.78	0.00	2.42	0.00	NAN
1984	39.00	109.50	NAN	55.35	NAN	4460.96	NAN	NAN	NAN	22.17	27.63	353.25	NAN	NAN	NAN	NAN	NAN	NAN	0.73	NAN	0.48	0.00	5.57	0.06	NAN
1985	17.00	75.40	NAN	60.48	NAN	2417.71	NAN	NAN	NAN	21.77	27.92	236.37	NAN	NAN	NAN	NAN	NAN	NAN	0.75	NAN	-0.07	0.41	1.71	0.05	NAN
1986	23.00	87.30	NAN	113.14	NAN	3187.87	NAN	NAN	NAN	23.63	27.82	144.33	NAN	NAN	NAN	NAN	NAN	NAN	0.74	NAN	-0.77	0.05	0.37	0.09	NAN
1987	25.50	90.70	NAN	89.20	NAN	3424.46	NAN	NAN	NAN	23.16	27.46	187.04	NAN	NAN	NAN	NAN	NAN	NAN	0.79	NAN	-1.32	0.25	0.87	0.16	NAN
1988	31.50	85.10	NAN	70.19	NAN	4047.02	NAN	NAN	NAN	23.84	27.72	142.81	NAN	NAN	NAN	NAN	NAN	NAN	0.76	NAN	-0.92	0.07	1.19	0.06	NAN
1989	NAN	133.40	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	66.58	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-1.07	1.29	1.75	0.00	NAN
1990	NAN	134.50	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	67.33	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-1.02	1.01	1.16	0.00	NAN
1991	NAN	197.90	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	46.91	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-0.77	0.78	0.17	0.46	NAN
1992	NAN	176.30	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	32.10	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN	-1.72	1.55	0.17	0.08	NAN
1993	75.00	195.39	256.23	80.32	31.00	NAN	NAN	NAN	NAN	23.78	30.66	68.53	NAN	NAN	NAN	NAN	NAN	12.05	NAN	NAN	-2.07	2.29	0.29	1.86	NAN
1994	NAN	219.44	300.78	NAN	48.00	NAN	NAN	NAN	NAN	NAN	NAN	66.17	NAN	NAN	NAN	0.89	26.05	18.20	NAN	NAN	-1.52	3.19	0.30	1.98	NAN
1995	173.00	215.13	294.16	82.84	71.00	10912.15	NAN	358.50	875.92	24.05	29.25	66.52	2.92	13.44	21.04	0.72	26.03	11.71	0.83	1.59	-1.17	2.14	0.54	1.74	NAN
1996	213.90	248.64	337.19	64.88	99.00	13368.38	NAN	307.34	1247.63	24.73	29.82	32.56	1.47	11.50	16.11	0.68	26.01	16.38	0.83	1.72	-0.92	1.95	0.16	4.78	6896.62
1997	193.00	237.22	331.10	53.46	146.00	12100.80	NAN	128.85	1257.47	24.94	29.74	35.85	4.16	12.80	19.08	0.64	26.44	23.24	0.80	2.74	-0.47	2.17	0.40	2.91	8643.90
1998	238.40	343.34	411.48	74.42	209.00	15707.48	NAN	39.89	1883.71	24.33	29.74	59.87	1.83	12.08	14.73	0.60	25.68	22.58	0.78	1.97	-0.06	2.46	0.31	0.41	10535.10
1999	268.40	395.92	438.41	72.20	258.00	17607.48	NAN	165.63	3010.18	24.08	29.32	64.13	2.54	13.24	16.90	0.63	25.46	28.92	0.75	3.24	-0.50	2.21	1.39	1.67	5134.32
2000	233.40	396.93	478.99	72.00	242.00	15893.36	NAN	280.34	0.00	24.74	29.78	76.29	2.34	17.06	19.79	0.58	25.57	36.70	0.78	3.60	0.07	1.52	0.79	11.44	4650.32
2001	183.30	443.52	557.50	126.03	221.00	14475.58	NAN	174.90	1184.11	24.29	29.27	73.28	2.42	19.05	19.56	0.63	25.15	32.12	0.79	2.36	-0.55	1.23	1.58	3.66	2217.94
2002	161.40	577.90	638.83	111.15	192.00	14133.20	980.00	134.00	399.17	24.45	29.18	57.30	0.15	14.17	13.43	0.70	25.61	25.14	0.78	2.77	-0.09	1.71	0.32	3.88	1617.59
2003	204.40	708.47	632.65	104.48	265.00	16916.16	196.00	576.74	1411.07	24.31	29.02	100.65	0.65	9.83	10.91	0.73	25.68	26.45	0.84	2.69	-1.30	0.57	1.03	6.69	1223.59
2004	353.70	823.52	663.55	78.00	263.00	26856.47	316.00	354.09	839.46	24.13	29.36	57.46	2.75	6.69	9.48	0.80	25.41	25.47	0.80	1.99	-0.43	0.84	0.64	3.44	1580.77
2005	312.90	713.5[illegible]	610.60	83.01	364.00	18587.50	198.00	187.02	4502.48	23.63	29.44	99.05	6.49	8.14	13.05	0.66	25.72	29.52	0.73	2.41	0.47	2.00	0.25	14.00	3133.06
2006	275.20	796.75	728.97	75.86	296.00	16288.53	61.00	121.30	0.00	23.39	29.37	77.47	10.23	10.55	13.57	0.55	25.96	29.22	0.75	3.62	1.03	0.83	0.80	18.92	5723.56
2007	281.20	730.86	623.75	66.34	389.00	18345.54	194.00	39.00	0.00	23.67	29.30	51.64	13.04	11.92	12.28	0.45	25.70	19.92	0.73	2.30	-0.73	0.98	0.29	7.77	6397.58
2008	226.10	691.63	635.97	72.25	423.00	12119.42	484.11	134.72	1046.18	23.84	28.57	92.82	8.52	13.98	20.50	0.52	24.98	35.20	0.73	1.96	0.03	0.37	1.24	6.51	4616.06
2009	333.10	686.80	734.99	91.70	324.00	24853.59	566.52	304.05	463.00	24.21	28.79	55.35	4.56	7.65	9.37	0.72	25.06	19.35	0.77	2.59	-0.61	0.08	0.57	5.42	6367.24
2010	273.00	594.57	574.15	105.47	350.00	21706.69	205.08	188.00	1036.00	24.53	29.22	70.88	4.59	13.20	15.45	0.74	25.20	32.55	0.80	2.35	1.54	1.08	0.16	2.55	5079.60
2011	**223.60**	**730.60**	**574.67**	**78.89**	**320.00**	**16823.67**	**97.34**	**123.89**	**1517.98**	**24.27**	**28.47**	**149.12**	**7.83**	**14.75**	**20.33**	**0.78**	**24.90**	**40.80**	**0.77**	**2.99**	**0.72**	**0.20**	**0.93**	**1.96**	**NAN**

Note: NAN = not a number.

Table 4. Set statistics from DFO-industry survey CK1101 conducted by MV Cody & Kathryn from June 1-18, 2011.

SET	SFA	DATE	LAT.	LONG.	SPEED (kts)	DIST. (n. m.)	DUR. (min)	WING. (m)	DEPTH (fth)	TEMP (°C)	RAW CATCH (kg)	STAND. CATCH (kg)	DENSITY (gm/m^2 or m.t./km^2)
1	15	01-Jun-11	445937	604568	2.40	1.25	0.02	15.92	169.00	2.20	182.62	199.48	4.95
2	15	01-Jun-11	445620	605403	2.36	1.45	0.02	16.12	172.60	2.03	78.47	73.08	1.81
3	15	01-Jun-11	445462	610668	2.15	1.08	0.02	16.60	172.60	2.10	44.00	53.29	1.32
4	15	01-Jun-11	445146	605258	2.41	1.13	0.02	16.44	172.60	2.26	125.19	146.39	3.63
8	15	03-Jun-11	444150	601102	2.22	1.04	0.02	16.64	179.80	3.88	104.78	132.25	3.28
9	15	03-Jun-11	444520	601810	2.26	0.97	0.02	16.80	312.90	3.04	108.86	144.51	3.59
10	15	03-Jun-11	445051	602592	2.11	1.03	0.02	16.59	197.80	2.79	103.87	131.64	3.27
12	15	03-Jun-11	445094	601842	2.65	1.38	0.02	17.28	190.60	2.82	85.73	78.23	1.94
13	15	03-Jun-11	444853	601608	2.11	1.01	0.02	16.67	294.90	3.09	83.46	107.27	2.66
14	15	03-Jun-11	445197	601249	2.00	0.97	0.02	16.53	273.30	3.04	190.06	256.57	6.37
15	15	03-Jun-11	445526	601222	2.21	1.00	0.02	17.43	269.70	2.95	193.69	241.00	5.98
18	17	04-Jun-11	451950	595429	2.31	1.03	0.02	16.20	140.20	2.63	155.58	203.27	5.05
20	17	04-Jun-11	452640	600493	2.53	1.15	0.02	16.48	154.60	2.75	169.65	194.21	4.82
21	17	04-Jun-11	452767	595890	2.36	1.10	0.02	16.45	154.60	2.80	124.74	150.27	3.73
22	17	04-Jun-11	453320	600011	2.51	1.15	0.02	16.57	151.00	2.73	179.17	203.76	5.06
24	17	04-Jun-11	453924	595131	2.25	1.04	0.02	16.78	143.80	2.69	176.00	219.37	5.45
25	13	08-Jun-11	453476	590809	2.16	0.94	0.02	16.51	187.00	3.75	54.89	76.58	1.90
26	13	08-Jun-11	454029	590809	2.38	1.16	0.02	17.13	197.80	3.78	18.60	20.44	0.51
27	13	08-Jun-11	453919	590349	2.67	1.20	0.02	17.76	262.50	4.17	77.57	78.95	1.96
28	13	08-Jun-11	453915	585855	2.17	1.09	0.02	17.26	215.80	3.97	34.93	40.52	1.01
29	13	08-Jun-11	454404	585894	2.19	1.01	0.02	17.37	215.80	3.98	75.30	93.07	2.31
30	13	08-Jun-11	454852	585384	2.10	1.22	0.02	17.22	226.60	3.92	171.46	177.58	4.41
31	13	08-Jun-11	454948	584722	2.14	1.02	0.02	17.69	255.30	4.32	335.66	405.77	10.07
32	13	08-Jun-11	454781	583595	2.36	1.07	0.02	17.74	273.30	4.21	155.13	177.31	4.40
33	13	08-Jun-11	454426	583665	2.40	1.09	0.02	17.10	233.70	4.00	42.64	49.70	1.23
34	13	09-Jun-11	454289	582056	2.26	1.06	0.02	17.63	230.10	3.69	69.40	80.76	2.00
35	13	09-Jun-11	454079	582820	2.33	1.08	0.02	15.85	370.40	4.19	66.68	84.96	2.11
36	13	09-Jun-11	453862	583252	2.30	1.04	0.02	16.43	377.60	4.14	105.23	134.37	3.34
37	13	09-Jun-11	453442	584423	2.20	1.10	0.02	17.05	215.80	3.67	40.82	47.21	1.17
38	13	09-Jun-11	453417	583451	2.33	1.14	0.02	17.22	280.50	3.82	167.83	185.65	4.61
39	13	09-Jun-11	453101	581991	2.25	1.03	0.02	16.91	363.20	3.39	31.75	39.62	0.98
40	14	10-Jun-11	445598	581982	2.26	1.10	0.02	17.09	258.90	2.81	834.16	968.72	24.05
41	14	10-Jun-11	445063	583175	2.19	1.07	0.02	17.22	237.30	2.60	407.78	483.25	12.00
42	14	10-Jun-11	444775	583810	2.31	1.13	0.02	17.11	248.10	2.60	388.28	435.78	10.82
43	14	10-Jun-11	445534	584330	2.07	1.11	0.02	17.11	258.90	2.40	419.12	478.39	11.88
44	14	10-Jun-11	444795	585275	2.32	1.10	0.02	17.71	258.90	2.43	400.07	445.72	11.07
45	14	10-Jun-11	445128	590281	2.26	1.15	0.02	17.04	240.90	2.25	382.20	424.92	10.55
46	14	10-Jun-11	444717	591127	2.20	1.11	0.02	16.70	223.00	2.22	278.05	325.35	8.09
47	17	11-Jun-11	451997	601844	2.04	1.04	0.02	16.38	194.20	2.52	232.70	296.78	7.37
48	17	11-Jun-11	452914	601457	1.85	0.95	0.02	15.87	161.80	2.60	183.71	263.66	6.55
52	17	11-Jun-11	452468	595737	2.23	1.01	0.02	15.94	161.80	2.80	110.22	148.54	3.69
54	17	11-Jun-11	451964	594418	2.40	1.11	0.02	15.63	129.50	2.54	78.47	98.20	2.44
55	17	12-Jun-11	453908	600161	2.06	1.00	0.02	16.26	140.20	2.32	257.92	343.69	8.53
56	17	12-Jun-11	453636	600116	2.29	1.13	0.02	16.09	161.80	2.63	152.41	182.02	4.52
57	17	12-Jun-11	453022	602293	2.35	1.16	0.02	16.10	158.20	2.50	164.20	190.76	4.74
58	17	12-Jun-11	452642	603221	2.18	1.06	0.02	15.47	194.20	2.47	141.52	187.08	4.64
59	17	12-Jun-11	452659	605213	2.34	1.13	0.02	13.82	107.90	1.85	157.40	219.26	5.44
60	17	12-Jun-11	452234	610142	2.41	1.19	0.02	13.60	100.70	1.78	108.86	146.38	3.63
61	15	16-Jun-11	444804	605344	2.51	1.07	0.02	17.06	233.70	2.60	314.34	373.68	9.28
62	15	16-Jun-11	444573	603733	2.20	1.04	0.02	16.65	212.20	2.48	348.82	436.69	10.84
63	15	16-Jun-11	445140	603151	2.40	1.12	0.02	17.01	212.20	2.60	119.30	135.84	3.37
64	14	17-Jun-11	443997	590183	2.44	1.11	0.02	16.06	226.60	2.21	300.28	367.85	9.13
65	14	17-Jun-11	444148	593391	2.38	1.15	0.02	16.47	208.60	3.39	219.54	251.46	6.24
66	14	17-Jun-11	444984	592855	2.30	1.11	0.02	16.24	233.70	2.96	635.49	765.83	19.01
67	14	17-Jun-11	445122	594228	2.28	1.14	0.02	16.04	212.20	3.30	158.76	189.51	4.70
68	14	17-Jun-11	444328	594714	2.50	1.18	0.02	17.27	248.10	3.52	207.75	222.68	5.53
69	14	17-Jun-11	444133	595949	2.40	1.16	0.02	16.72	208.60	3.90	108.86	122.11	3.03
70	14	17-Jun-11	444664	595888	2.31	1.18	0.02	16.82	212.20	2.81	99.34	108.45	2.69
71	14	18-Jun-11	445449	595776	2.37	1.20	0.02	16.40	187.00	3.05	209.56	231.90	5.76
74	15	18-Jun-11	445465	602627	2.43	1.19	0.02	17.10	244.50	2.80	169.65	181.60	4.51

Table 5. Minimum survey population numbers at age from modal analysis. Numbers x 10^6.

Age	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
1[1]	-	-	-	-	-	980	196	316	198	61	194	484	567	263	97	362
2	129	40	166	280	175	134	616	354	187	121	39	114	304	188	124	220
3	1159	785	27	757	362	383	312	3118	652	880	506	396	267	1020	1094	747
4	1257	1884	3010	0[2]	1184	399	1506	839	4502	0[2]	0[2]	1190	463	1036	1518	1492
5+	1539	2047	1952	3374	2110	1847	1727	3324	2224	5106	5506	3017	6020	4109	3618	2985
TOTAL	4084	4755	5155	4412	3831	2763	4161	7636	7763	6169	6244	5201	7622	6616	6451	5274
Age 4+ males[3]	1578	2243	3235	1784	1771	938	1526	1549	4956	3916	2804	3317	4263	3454	3358	2481
Primiparous[4]	709	889	736	728	817	678	551	870	786	771	1739	892	1492	1324	930	872
Multiparous	509	647	991	863	706	630	1188	1698	1183	480	1157	482	1295	630	945	870
Total females	1218	1535	1727	1591	1523	1308	1739	2568	1969	1251	2896	1374	2787	1954	1875	1742

1 Belly-bag.
2 Four year olds of the 1996, 2002 and 2003 year classes were not distinguishable in the MIX analysis. These year classes appear to be small and are contained in the ages 3 or 5+ categories.
3 Total population less ages 2 and 3 males, transitionals and females.
4 Includes transitionals.

Table 6. Survey biomasses, commercial shrimp catches, and exploitation rates (catch/biomass) by survey strata (13-15, offshore part), and the inshore area (17), 1995-2011.

	SFA	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	mean
Biomass (mt)	13	4838	6838	5921	7188	9517	5866	4089	3114	7047	12184	9687	6129	7507	4144	6208	2688	4537	6324
	14	9068	12094	9472	11279	11040	9364	12325	12020	12035	20228	20035	18929	15957	12710	20544	16009	14614	13984
	15	5300	6610	4737	4549	7807	7268	2073	2766	3751	4399	4378	5130	5345	4227	7235	4784	4223	4975
	17	4415	3663	6221	9530	8262	9365	6541	2872	5296	11627	10333	7581	9622	9823	11438	13731	7136	8086
	Total	**23621**	**29205**	**26351**	**32546**	**36626**	**31863**	**25028**	**20773**	**28130**	**48438**	**44433**	**37769**	**38431**	**30904**	**45424**	**37212**	**30510**	**33369**
Catch (mt)	13	168	55	570	514	612	301	588	254	581	2003	1186	629	235	212	11	166.74	3	476
	14	2265	2299	2422	2012	1503	2009	1616	1553	1622	754	1441	1996	2518	2697	2029	2377.97	2900	2001
	15	715	817	583	618	589	1609	1132	265	225	339	600	445	668	534	540	884.085	906	675
	17	0	0	0	787	2121	1498	1629	873	330	143	389	915	1161	879	896	1471.21	692	811
	Total	**3148**	**3171**	**3575**	**3931**	**4825**	**5417**	**4965**	**2945**	**2758**	**3239**	**3616**	**3985**	**4582**	**4321**	**3477**	**4900**	**4500**	**3962**
Exploitation (%)	13	3.5	0.9	9.1	7.2	6.5	5.1	13.8	8.2	8.3	16.4	12.2	10.3	3.1	5.1	0.2	6.2	0.1	7.3
	14	25.2	20.1	24.1	17.8	13.7	21.5	12.6	12.9	13.5	3.7	7.2	10.5	15.8	21.2	9.9	14.9	19.8	15.3
	15	13.6	13.1	11.6	13.6	7.6	22.2	52.4	9.6	6.0	7.7	13.7	8.7	12.5	12.6	7.5	18.5	21.4	14.2
	17	0.0	0.0	0.0	8.3	25.8	16.1	23.9	30.4	6.2	1.2	3.8	12.1	12.1	8.9	7.8	10.7	9.7	10.4
	Total	**13.4**	**11.5**	**12.8**	**12.1**	**13.2**	**17.1**	**19.1**	**14.2**	**9.8**	**6.7**	**8.1**	**10.6**	**11.9**	**14.0**	**7.7**	**13.2**	**14.7**	**12.4**

Table 7. Fish bycatch of the commercial shrimp fishery by strata (14, 15, inshore-17), but fleet and by season from observer data of 119 sets from 2010-2011.

	TOTAL BYCATCH		BYCATCH BY AREA				BYCATCH BY FLEET		BYCATCH BY SEASON	
SPECIES	Est. Weight (Kgs)	TOTAL %	SFA 13	SFA 14	SFA 15	SFA 17	GULF	SCOTIA-FUNDY	SPRING	FALL
SHRIMP	167133	97.29%	92.70%	97.68%	96.35%	98.95%	97.11%	97.41%	97.93%	95.23%
SILVER HAKE	1449	0.84%	0.30%	0.59%	1.56%	0.07%	1.48%	0.42%	0.54%	1.82%
HERRING(ATLANTIC)	1097	0.64%	1.97%	0.62%	0.66%	0.43%	0.37%	0.82%	0.48%	1.16%
AMERICAN PLAICE	446	0.26%	0.30%	0.21%	0.37%	0.17%	0.19%	0.31%	0.22%	0.39%
WITCH FLOUNDER	363	0.21%	0.30%	0.22%	0.26%	-	0.10%	0.28%	0.21%	0.21%
REDFISH UNSEPARATED	321	0.19%	0.16%	0.17%	0.27%	-	0.17%	0.20%	0.15%	0.30%
EELPOUTS(NS)	293	0.17%	-	0.23%	0.12%	0.01%	0.04%	0.26%	0.20%	0.09%
CAPELIN	219	0.13%	3.45%	0.07%	0.04%	0.11%	0.26%	0.04%	0.03%	0.44%
TURBOT,GREENLAND HALIBUT	137	0.08%	0.53%	0.04%	0.14%	0.01%	0.05%	0.10%	0.08%	0.08%
SNAKE BLENNY	61	0.04%	-	0.04%	0.03%	0.02%	0.04%	0.03%	0.04%	0.01%
ALEWIFE	44	0.03%	-	0.01%	0.00%	0.20%	0.01%	0.03%	0.01%	0.08%
THORNY SKATE	26	0.02%	0.07%	0.02%	0.00%	-	0.03%	0.01%	0.01%	0.03%
FOURBEARD ROCKLING	22	0.01%	-	0.02%	0.01%	-	0.02%	0.01%	0.01%	0.02%
SAND LANCES (NS)	22	0.01%	-	0.01%	0.03%	-	0.01%	0.01%	0.02%	0.00%
WHITE BARRACUDINA	19	0.01%	0.03%	0.01%	0.02%	-	0.01%	0.01%	0.01%	0.01%
DAUBED SHANNY	18	0.01%	-	0.01%	0.02%	-	0.01%	0.01%	0.01%	-
MARLIN-SPIKE	17	0.01%	-	0.01%	0.02%	-	0.02%	-	0.01%	-
COD(ATLANTIC)	12	0.01%	-	0.01%	0.01%	0.02%	0.00%	0.01%	0.01%	0.01%
YELLOWTAIL FLOUNDER	12	0.01%	-	0.00%	0.02%	-	0.00%	0.01%	0.00%	0.02%
SQUIDS	10	0.01%	0.07%	0.01%	0.01%	-	0.01%	0.00%	0.00%	0.02%
SHANNY(NS)	11	0.01%	0.07%	0.01%	0.00%	-	0.02%	-	-	0.03%
ALLIGATORFISH	9	0.01%	-	0.01%	0.00%	-	0.01%	-	-	0.02%
SKATE(NS)	9	0.01%	0.03%	0.00%	0.01%	-	0.01%	-	0.01%	0.00%
ATLANTIC SEA POACHER	8	0.00%	-	0.00%	0.01%	-	0.00%	0.00%	0.01%	-
RHODICHTHYS SPP.	5	0.00%	-	0.00%	0.01%	-	-	0.00%	0.00%	-
SNOW CRAB (QUEEN)	5	0.00%	-	0.00%	0.01%	-	0.00%	0.00%	0.00%	0.00%
WHITE HAKE	4	0.00%	-	0.00%	0.00%	-	0.01%	-	0.00%	-
WINTER FLOUNDER	4	0.00%	-	-	0.01%	-	-	0.00%	0.00%	-
SCULPINS	3	0.00%	-	0.00%	-	0.01%	0.00%	0.00%	0.00%	0.00%
MACKEREL(ATLANTIC)	2	0.00%	-	0.00%	0.00%	-	-	0.00%	0.00%	-
POLLOCK	2	0.00%	-	-	0.00%	-	0.00%	0.00%	0.00%	0.00%
STRIPED ATLANTIC WOLFFISH	2	0.00%	-	0.00%	0.00%	-	0.00%	0.00%	-	0.00%
HERMIT CRAB	1	0.00%	-	0.00%	-	-	0.00%	-	-	0.00%
SQUIRREL OR RED HAKE	1	0.00%	-	0.00%	-	-	-	0.00%	0.00%	-
TOAD CRAB,UNIDENT.	1	0.00%	-	-	0.00%	-	-	0.00%	0.00%	-
WRYMOUTH	1	0.00%	-	-	0.00%	-	0.00%	-	-	0.00%
HAGFISH	1	0.00%	0.03%	-	-	-	0.00%	-	-	0.00%
SEASNAIL	1	0.00%	-	0.00%	-	-	0.00%	-	-	0.00%
% BYCATCH		2.71%	7.30%	2.32%	3.65%	1.05%	2.89%	2.59%	2.07%	4.77%

Note: Weights may be overestimated due to data collection restrictions (minimum recorded weight is 1 kg).

FIGURES

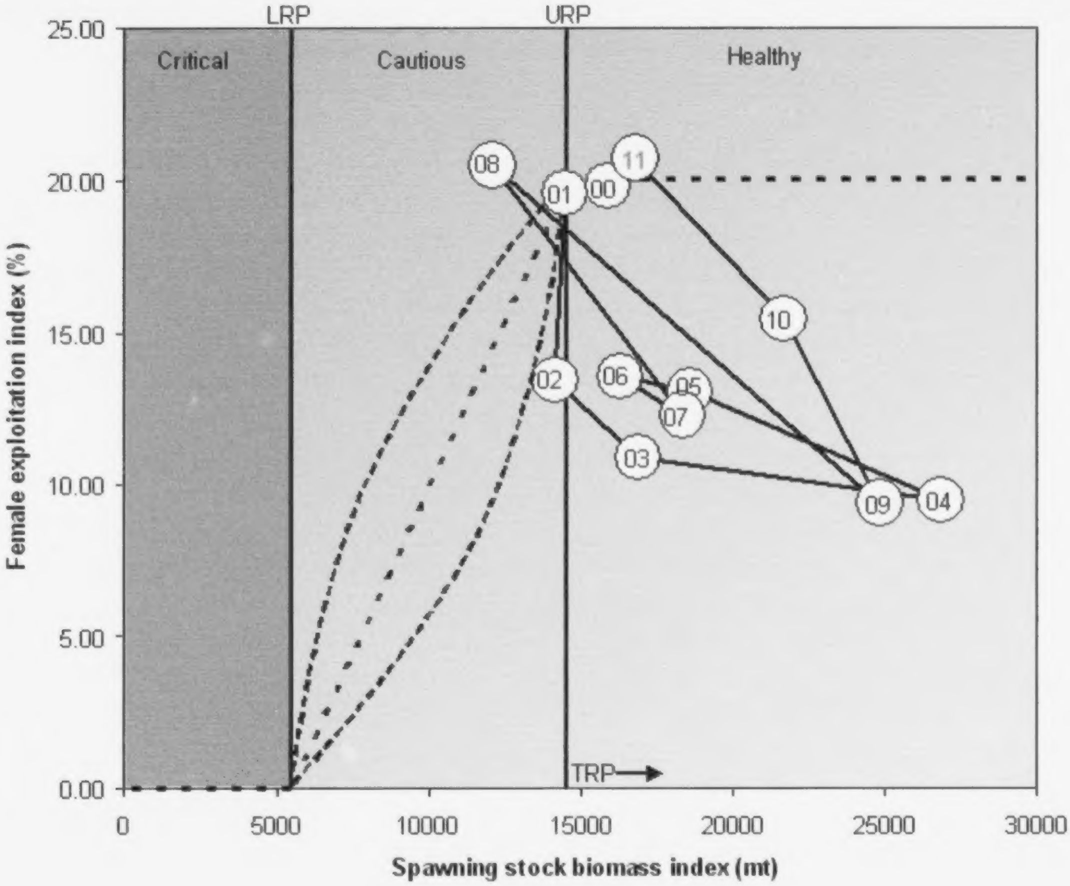


Figure 1. Graphical representation of the precautionary approach for Scotian Shelf shrimp. The dotted lines in the cautious zone represent a range of management actions possible, depending on whether the stock is stable, increasing or decreasing, or on trends in other indicators of stock or ecosystem health. Note that female exploitation is used as a removal reference, unlike past years (total exploitation was used).

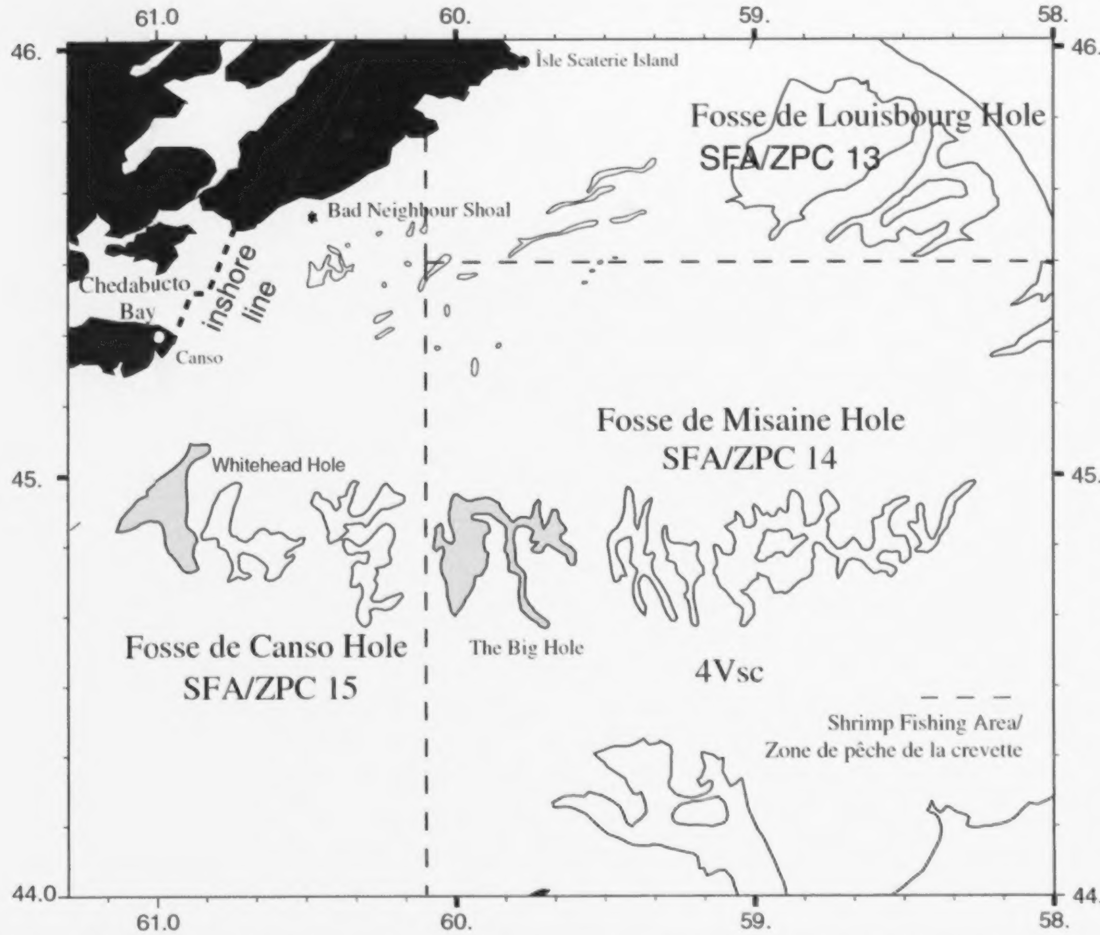
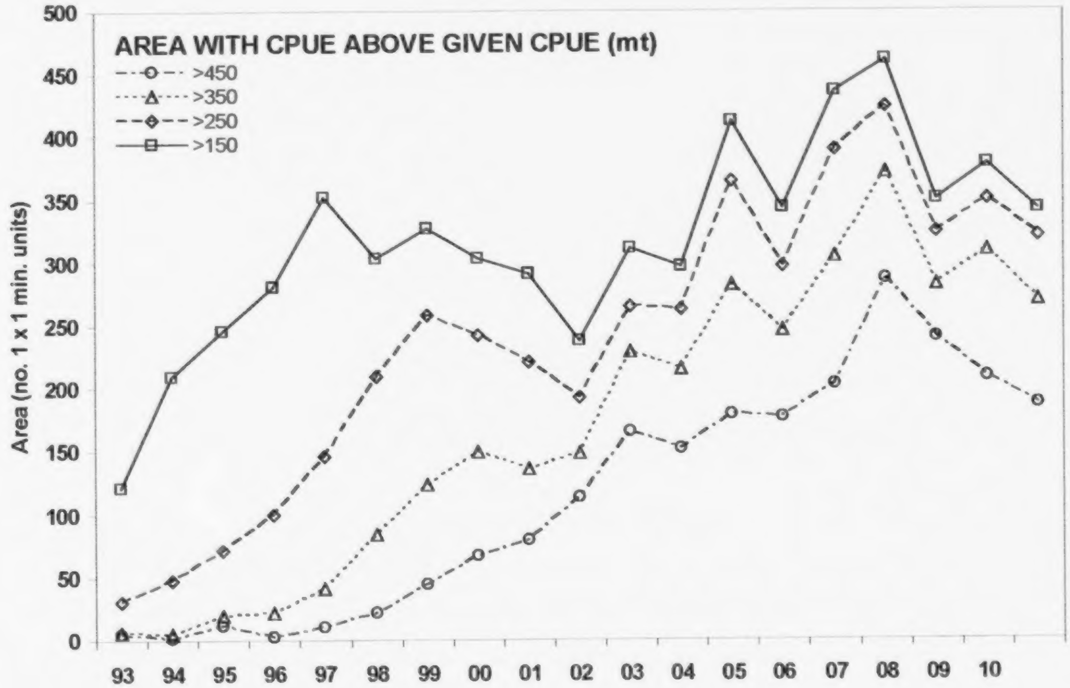


Figure 2. Shrimp Fishing Areas (SFAs) on the eastern Scotian Shelf. The inshore line prohibits trawlers from fishing inside Chedabucto Bay during the trapping season (fall to spring). Note the distinction between SFAs used to report catches and survey strata defined offshore (strata 13, 14, 15) by the 100 fathom contour (solid lines) and inshore (stratum 17) by the extent of LaHave clay north of 45°10' and west of 59°20' on surficial geology maps).



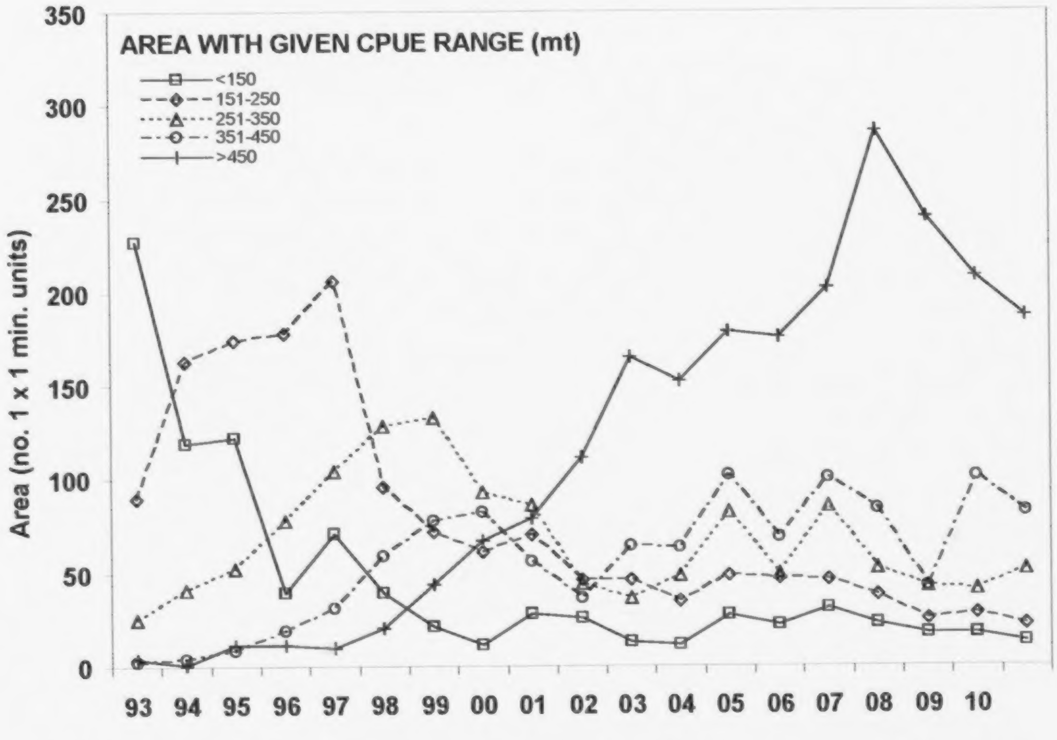


Figure 3. Number of 1 minute square unit areas fished by the shrimp fleet with mean catch rates above (top) and within (bottom) the values or ranges specified in the legend.

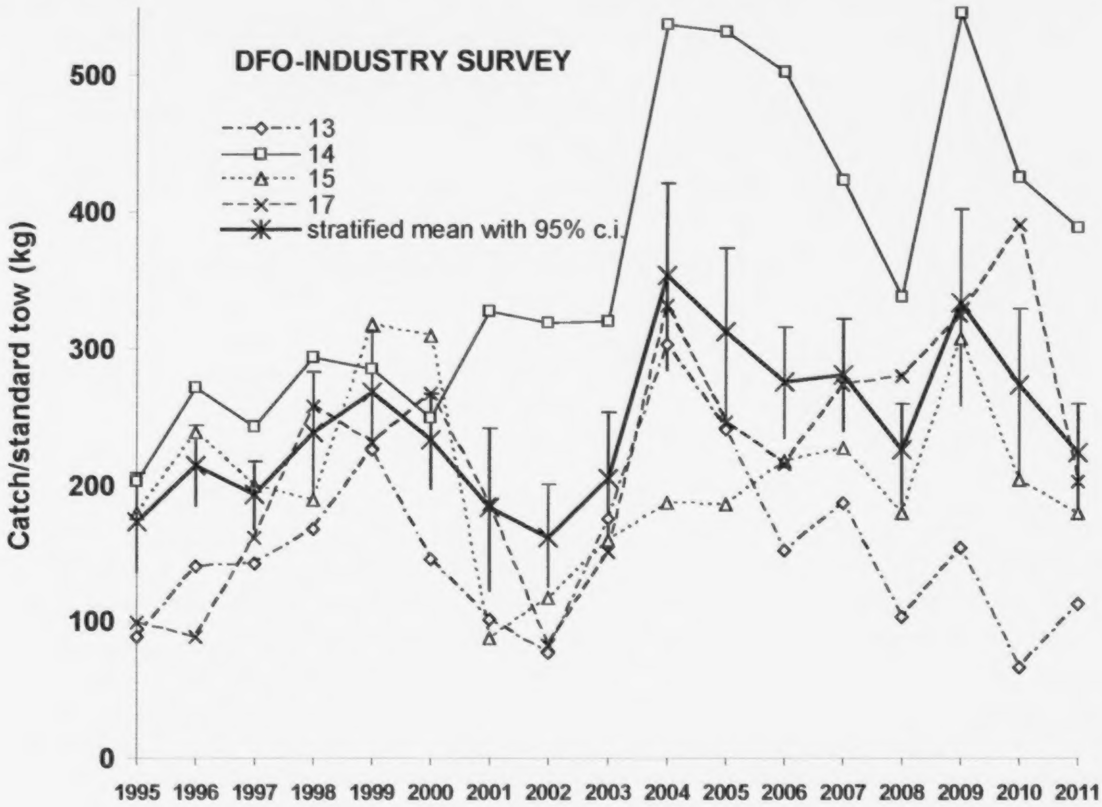


Figure 4. Stratified catch/standard tow for DFO-industry co-operative surveys from 1995-2011, and estimates for the individual strata, which approximately correspond to the main shrimp holes and SFAs. Stratum 13 - Louisbourg Hole and SFA 13; Stratum 14 - Misaine Holes and SFA 14; Stratum 15 - Canso Holes and the offshore part of SFA 15. The 'Inshore', or Stratum 17, is comprised of inshore parts of SFA 13-15.

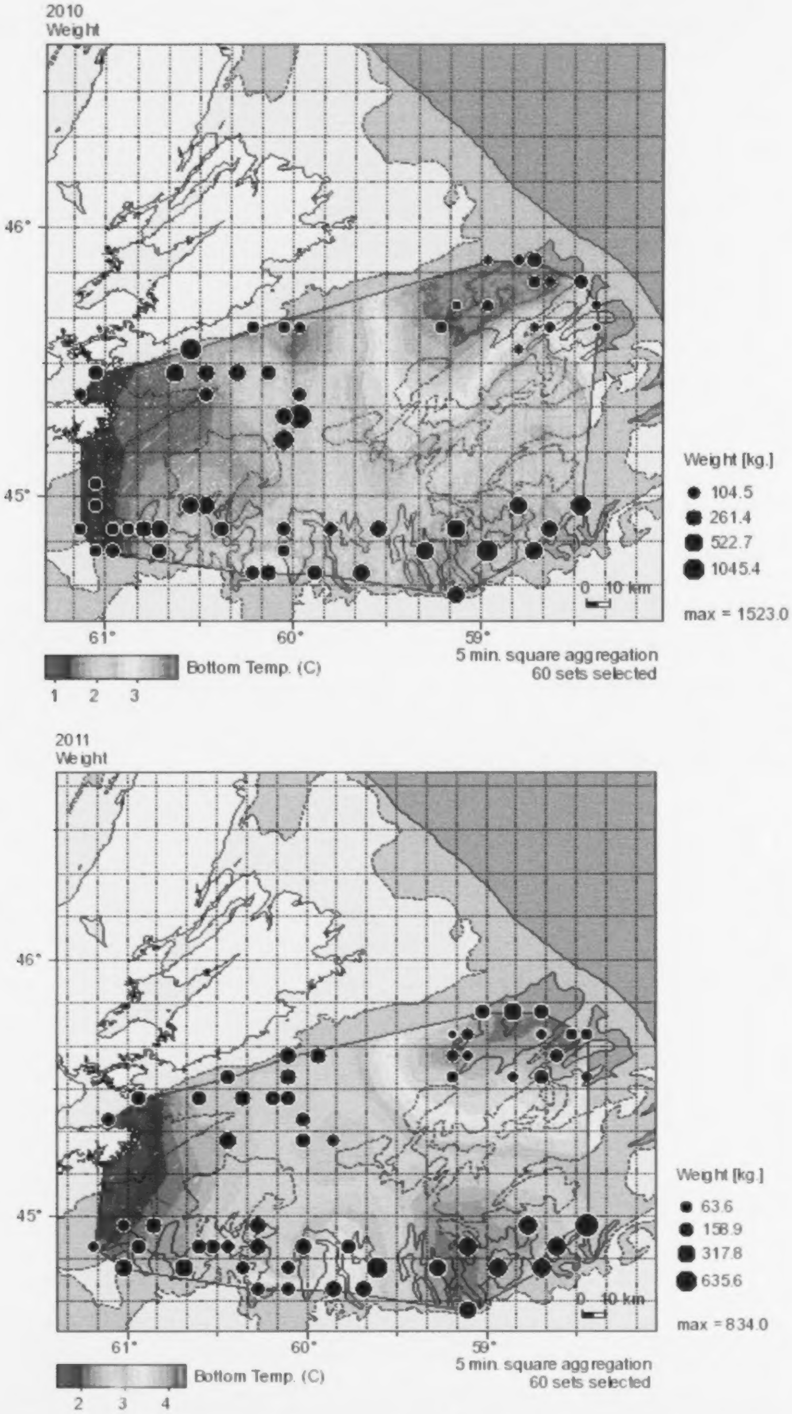


Figure 5. Distribution of catches (kg/standard 30 minute tow) and bottom temperatures from DFO-industry surveys 2010 (top) and 2011 (lower). See previous research documents for distributions prior to 2010.

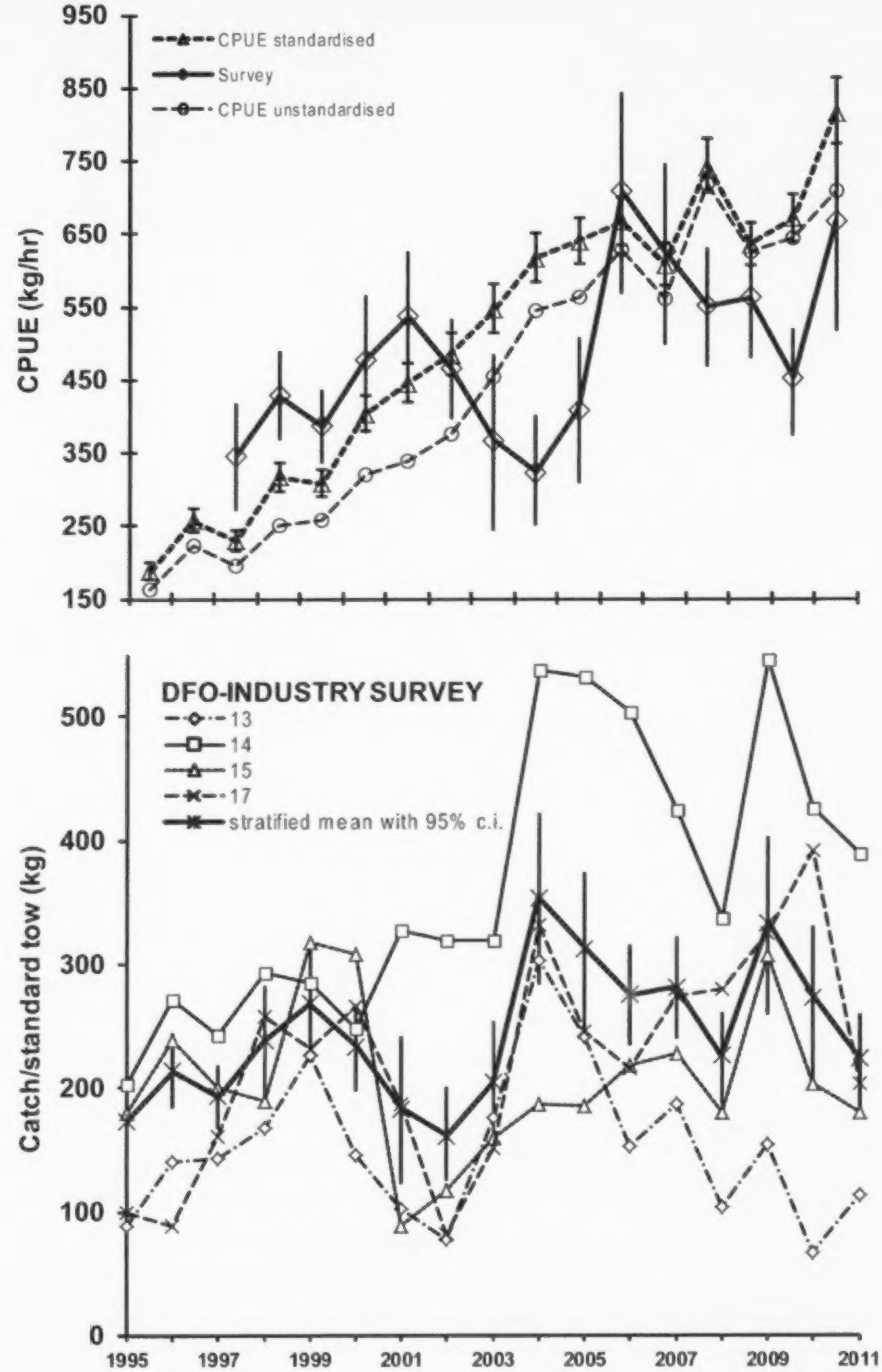


Figure 6. Survey stratified estimate (solid line) and standardised CPUE with 95% confidence intervals (dashed line) (top), and unstandardised commercial CPUE for each fishing area. Note that SFA 15 includes the inshore, but the latter is also shown separately since fishing began there in 1998 (bottom).

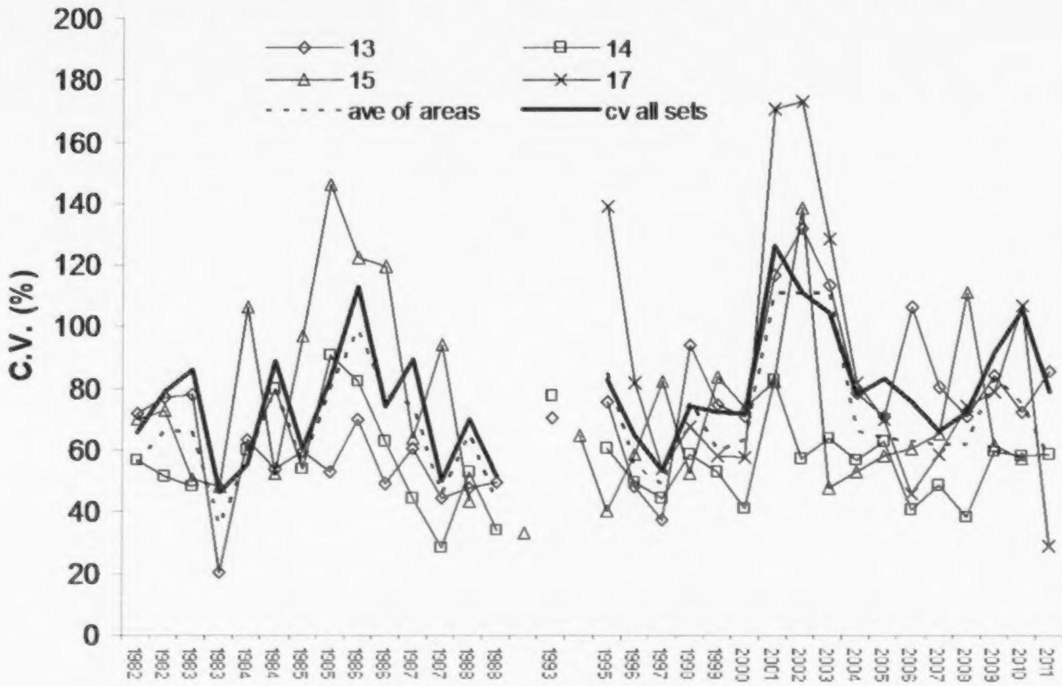


Figure 7. Coefficients of variation (CV) for shrimp survey strata 13, 14, 15, and 17. Note that the earlier survey series has two values per year, one for the spring and one for the fall survey. The use of fixed stations in 14 likely acts to constrain interannual changes in CV relative to other areas with random stations.

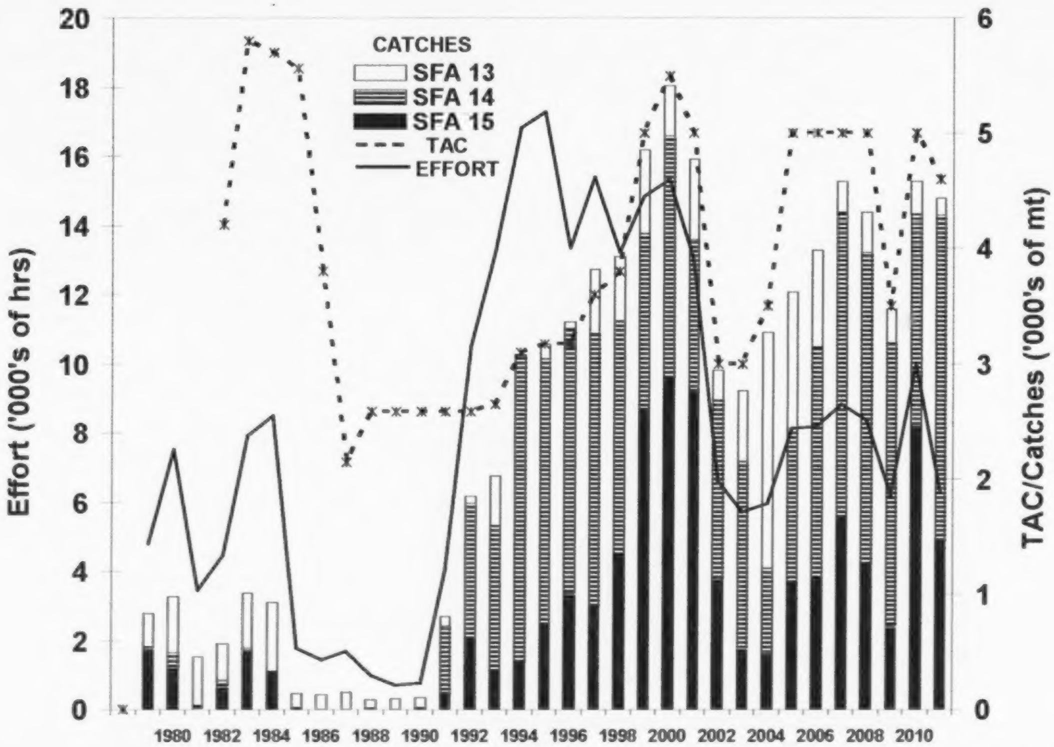


Figure 8. Landings, TACs, and effort by SFA.

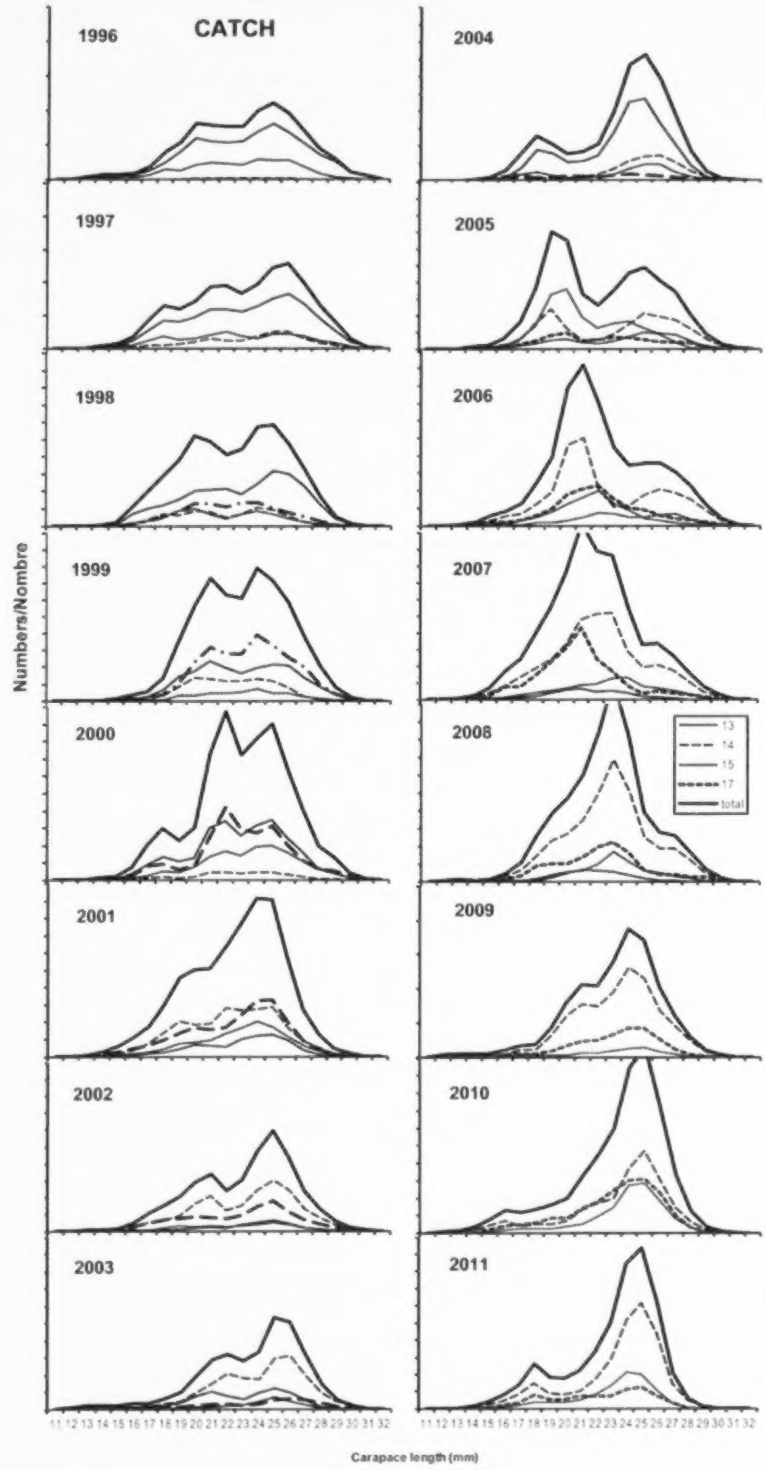


Figure 9. Catch at length from commercial sampling, 1995-2011.

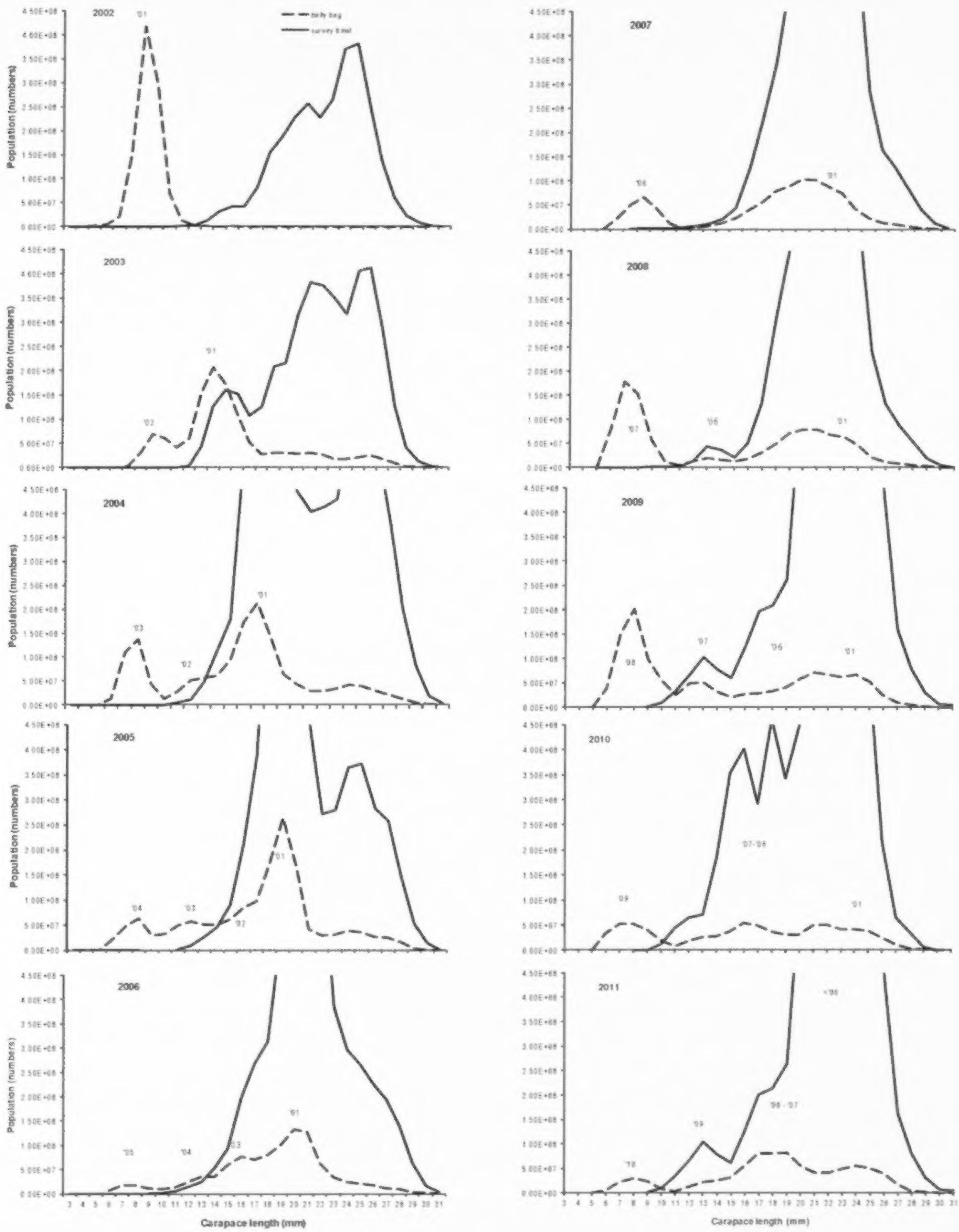


Figure 10. Population estimates from belly-bag and main trawl catches for the 2002-2011 survey. Note that the 2002 belly-bag estimate was made only for 1 year olds.

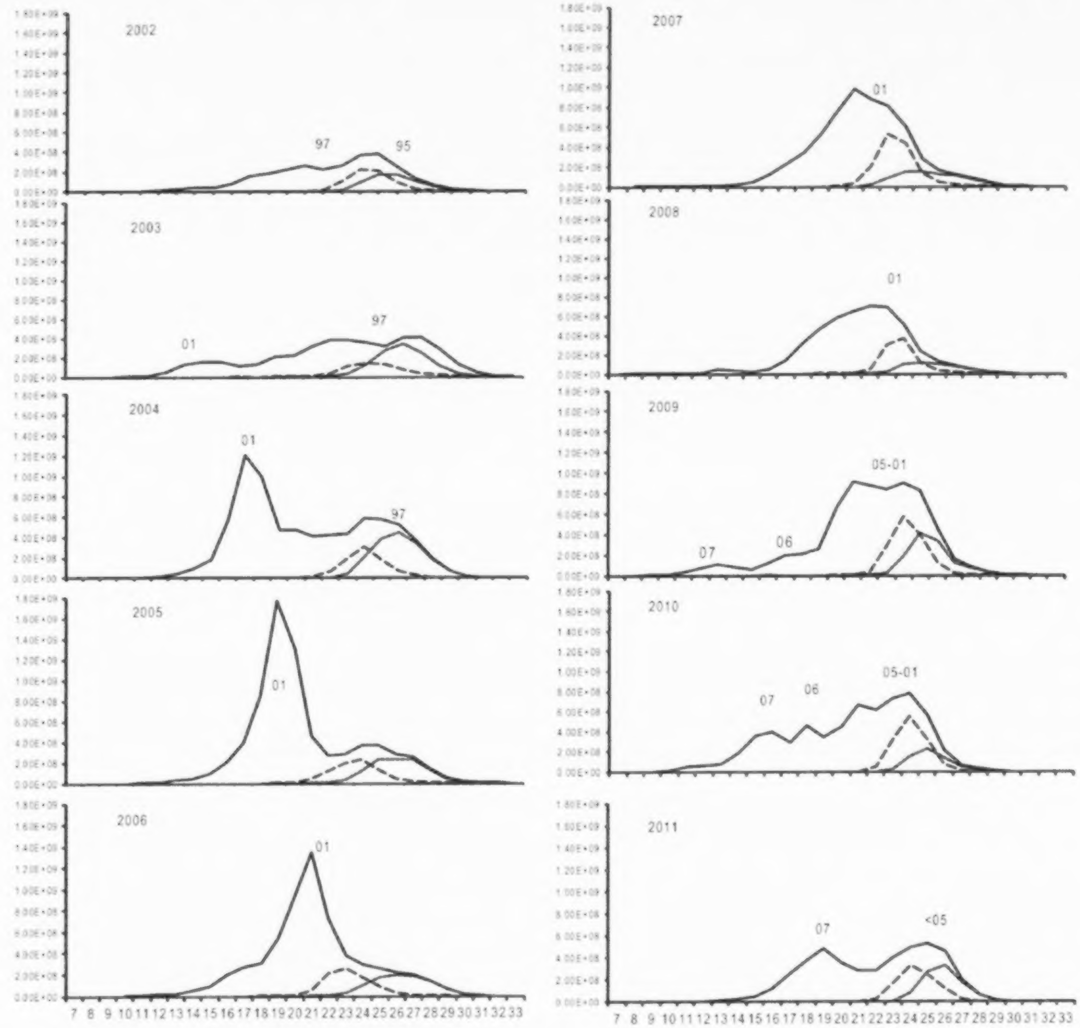


Figure 11. Population estimates at length from DFO-industry surveys 2003-2011 (solid line). The heavy dotted line in each figure represents transitional and primiparous shrimp, and the stippled line represents multiparous shrimp.

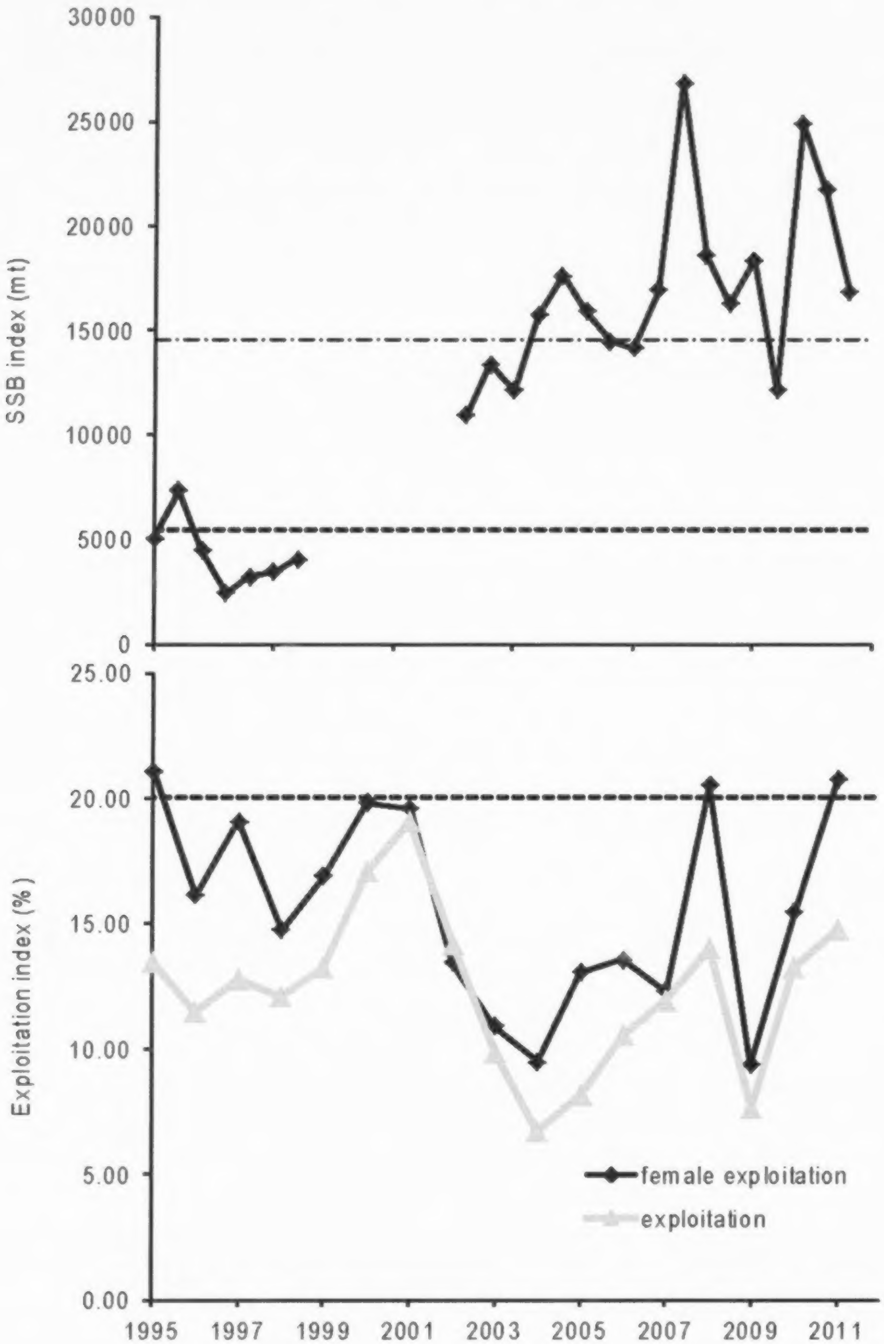
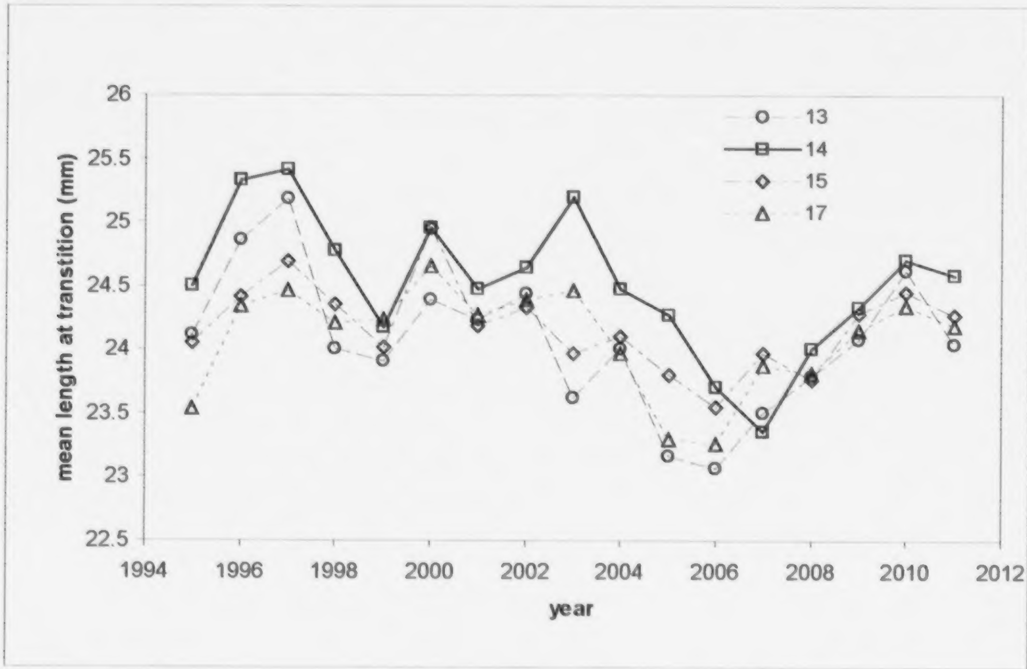


Figure 12. Changes in the spawning stock biomass index (top) and the exploitation index (bottom) for the Eastern Scotian Shelf shrimp population. The dashed line shows the lower limit reference point at 30% of the mean value during the 2000-2010 high-productivity period (top) and the limit reference point of 20% for the exploitation index (bottom).



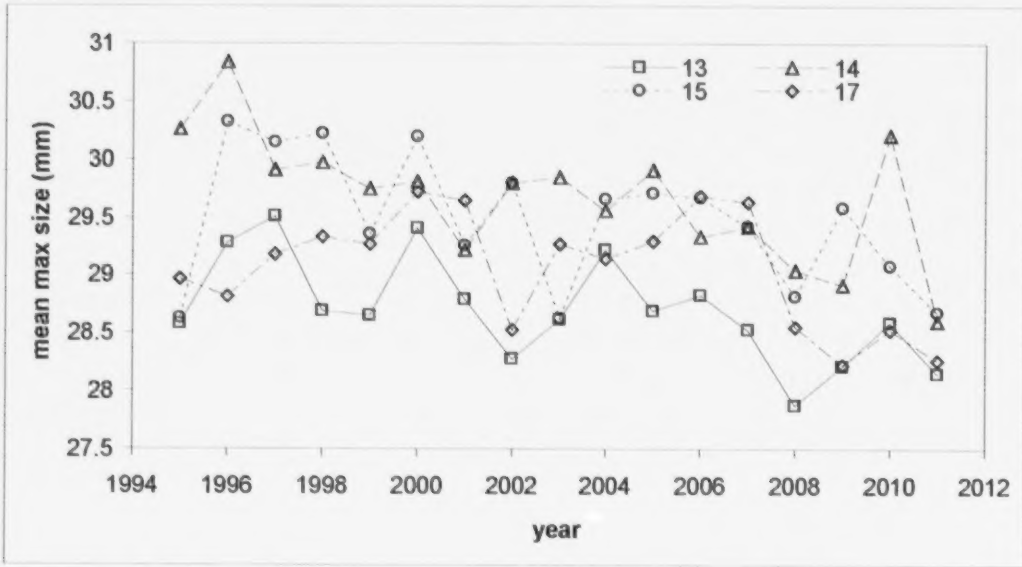


Figure 13. Average size at (top) - sex transition, and - maximum size (bottom) by SFA for the DFO-industry surveys 1995-2011.

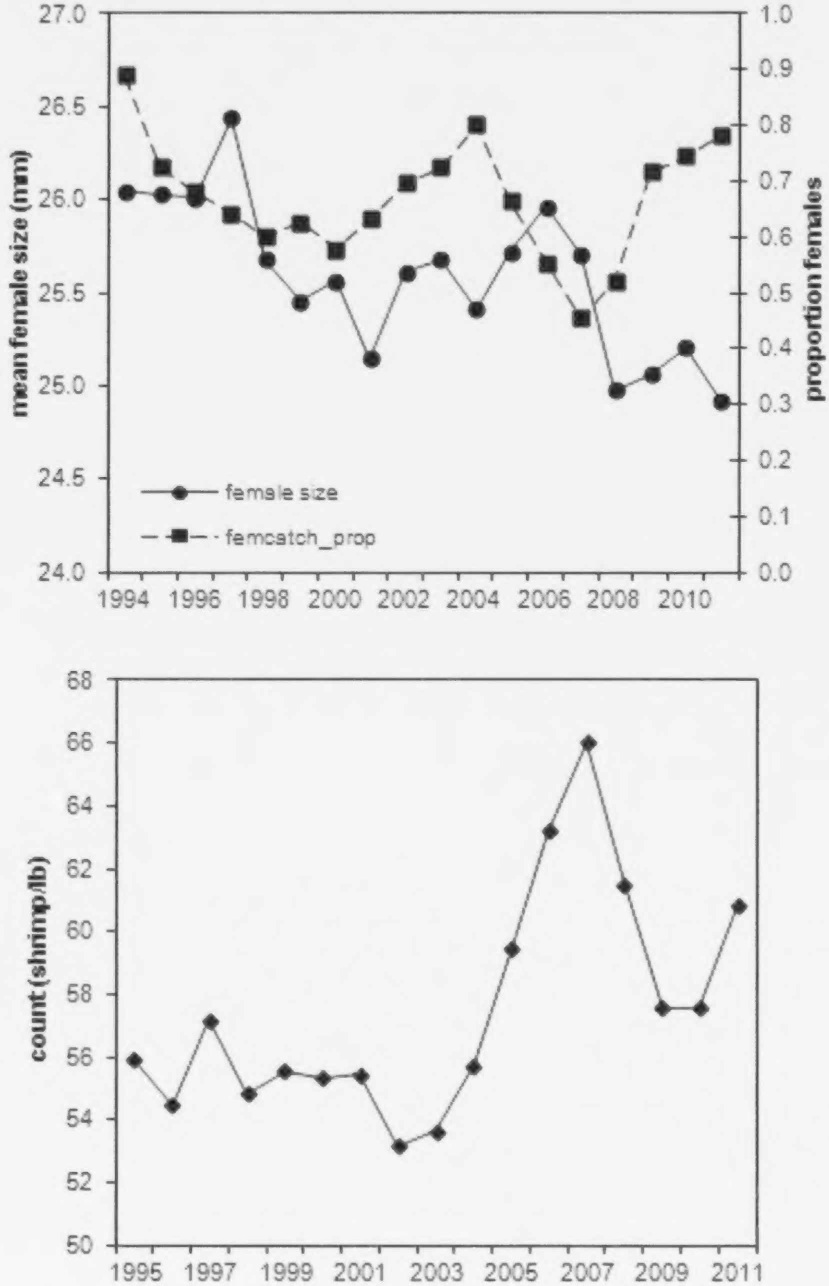


Figure 14. Mean female carapace length, proportion of females (top) and the count per pound (bottom) in the commercial shrimp trawl fishery.

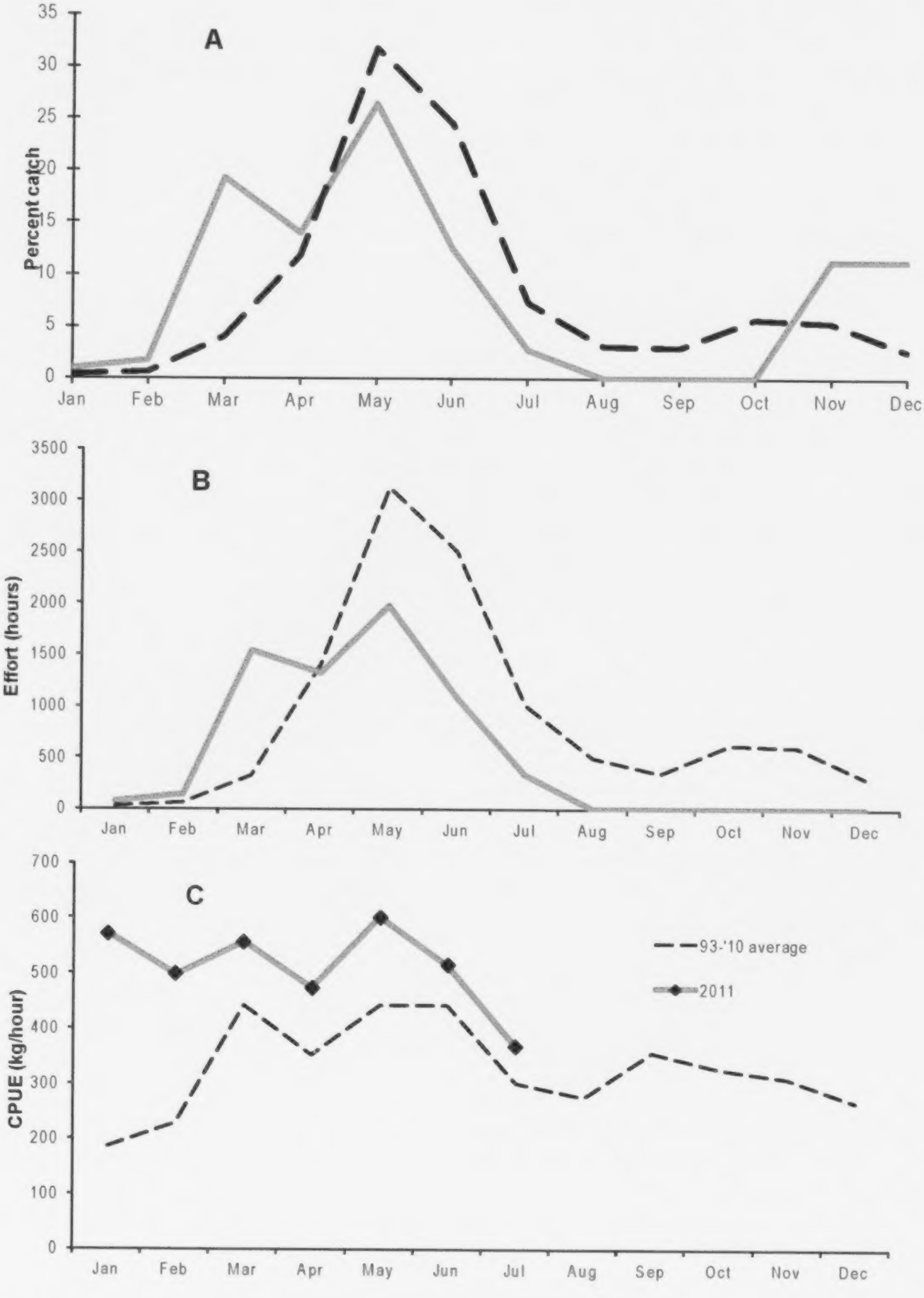


Figure 15. A - catches from the shrimp fishery as a percentage of the total catch, pro-rated for November-December data, B - average CPUEs, and C - total effort, by month.

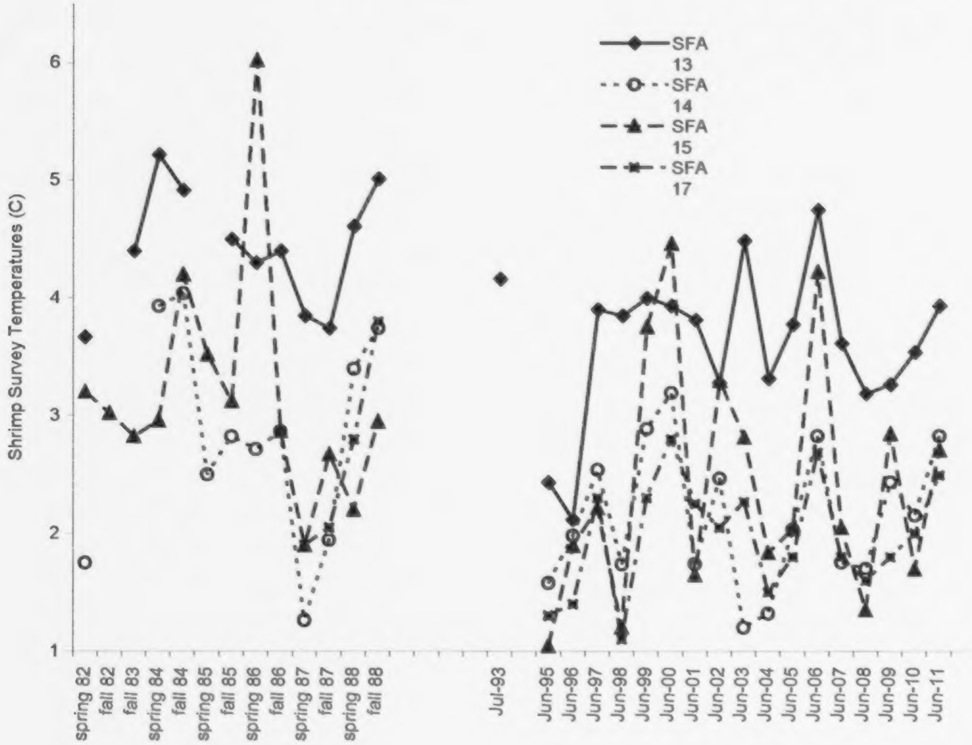


Figure 16. Mean bottom temperatures from shrimp surveys by SFA. Note that both spring and fall values were available from the earlier series (1982-1988), but only one survey (June) was conducted annually in the recent series.

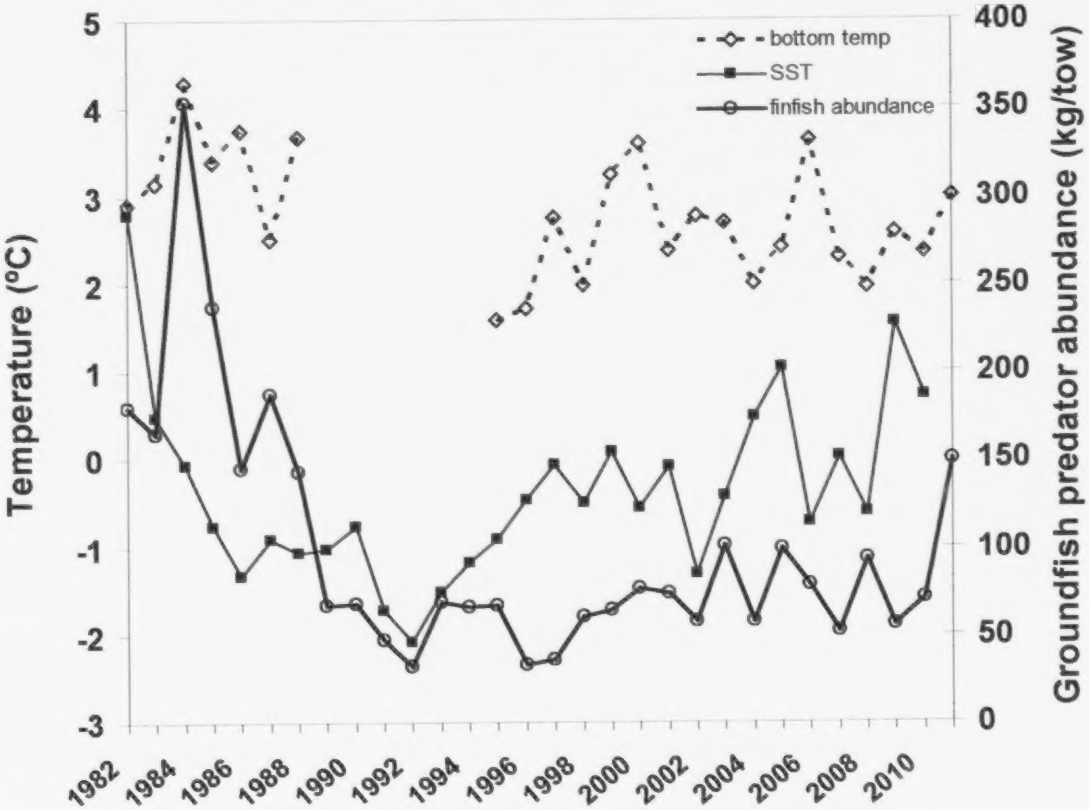


Figure 17. Bottom temperatures and predator abundance on the eastern Scotian Shelf shrimp grounds.

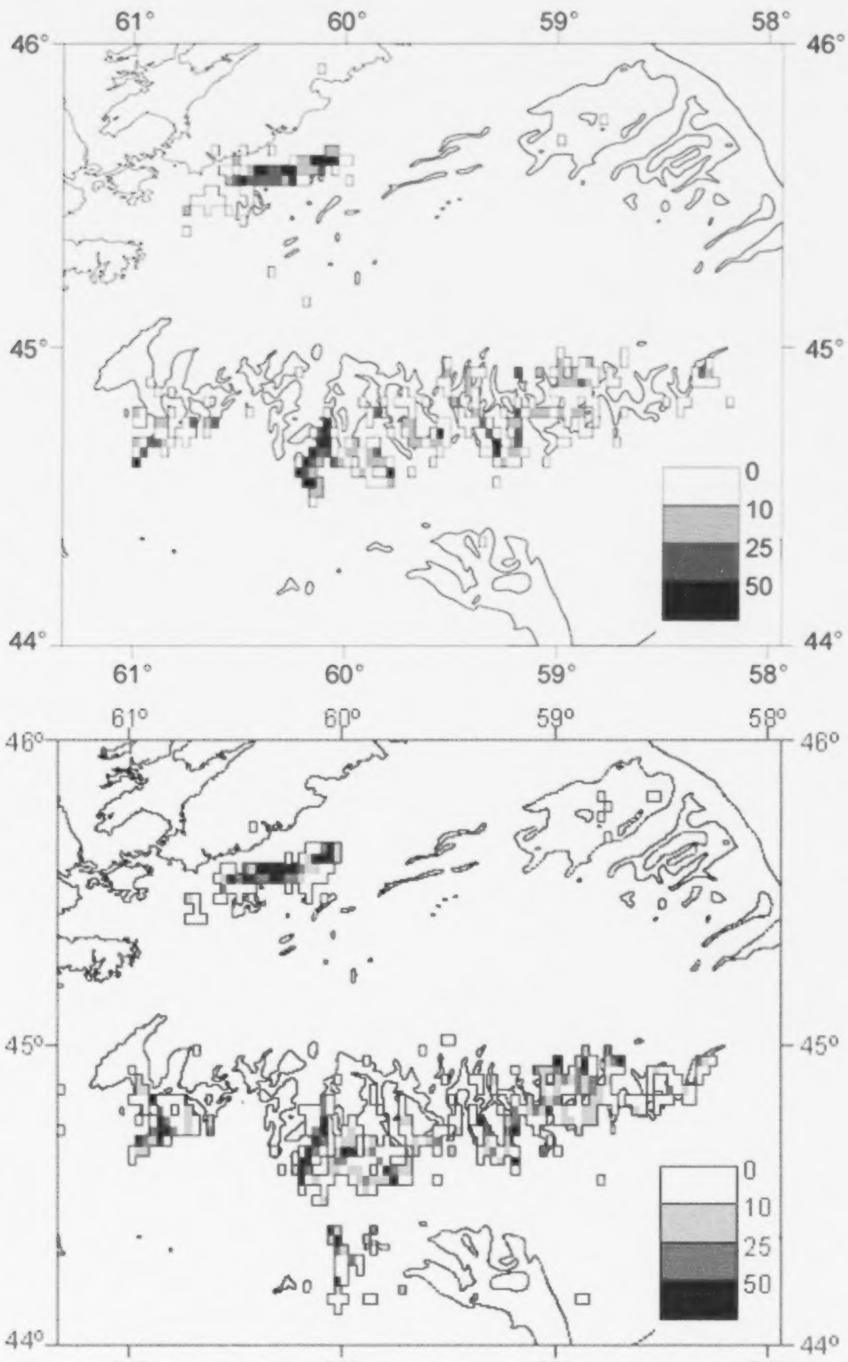


Figure 18. Annual effort by trawlers 2010 (top) and 2011 (bottom), cumulative by 1 minute squares.